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ALEXANDER EUGENIEVICH FERSMAN

November 8, 1883—May 20, 1945

The death of Alexander Fersman, Member of the Academy of Sciences of the USSR, is a great loss to Soviet and World Science. Particularly it is a sad blow to his collegues in the editorial board of these Comptes Rendus of which he was a permanent member for many a year. Among this country's workers in the field of natural science, Fersman ranked as an outstanding authority in mineralogy and geochemistry, second only to his teacher and friend, W. I. Vernadsky. A man of exceptional gifts and varied interests, he had a profound love for Science, to which he had devoted his life.

Fersman was born in St. Petersbourg, in 1883. He spent his childhood and received his early education in the south of Russia: in Odessa and Novorossiysk. Transferred to the Moscow University in 1904 he began his scientific career under the guidance of W. I. Vernadsky. After his graduation from this University in 1907, he went abroad to complete his education. Returning to Russia, he took an active part in organizing the Shaniavsky Public University and here occupied the chair of mineralogy. In 1912 he entered the Academy of Sciences as curator of the Mineralogical Museum. At that time he made an extensive study of the mineralogy of the Urals, studied the magnesium silicates, and continued his earlier researches on ceolites and pegmatite veins. Influenced by the ideas of W. I. Vernadsky, he closely approached the problems of geochemistry, and soon became a leading authority in this field.

During the World war of 1914—1918 he transferred his attention to the mineral resources of Russia. As secretary of the Committee for the Study of the Productive Forces of Nature, Fersman revealed himself as an able organizer of scientific research and did much to extend expeditionary activities for the benefit of science and industry. In 1916 he raised the question of strategic raw materials. It was then that he made numerous trips to Asia, the Urals, Transbaikal and other places to study the mineral resources of these regions. His work in this sphere was even more intense after the Revolution, when Wladimir Lenin urged the Academy to enter upon a systematic study of the Country's natural wealth.

In 1919 Alexander Fersman was elected to the Academy of Sciences and appointed director to its Mineralogical Museum.

Exploration of the Khibiny Tundra was carried out under his guidance and participation. This was no easy task in those years of economic dislocation, but the combined strength of his youthful enthusiasm, personal charm and authority as a scientist helped to surmount all difficulties. As a result Soviet and world science were enriched by the discovery of new minerals and rocks, new associations of elements, some of them of primary economic importance: phosphorus, rare earths, niobium, zirconium, and others. Research and exploitation of the mineral wealth of Khibiny and afterwards of the entire Kola Peninsula, are connected primarily with the name of Alexander Fersman whose rôle in this undertaking cannot be overestimated.

Devoting much energy to the exploration of the Kola Peninsula, he at the same time conducted research in other districts—in the emerald mines of the Urals, the radium-bearing deposits of Ferghana, the sulphur hills of the Kara-Kum desert, and other places. During the same period he wrote numerous scientific works. Special mention deserve his works on morphology and geochemistry of Tuya-Muyuna and his well-known monograph «Pegmatites, their Importance for Science and Industry», published in 1931 and recording the results of 25 years of research in this complex and interesting domain. This book has won itself a wide fame beyond the confines of this country. From 1933—1939 Fersman published four volumes of his «Geochemistry», which is the outcome of immense work done by the author in laying down the foundations of a new science. In the domain of geology and mineralogy there is hardly another work so rich in new ideas, with so broad a visualization of problems and so abundant in facts upon which the author has based his conclusions.

Fersman devoted constant attention to questions connected with the organization of scientific work. In his early years with the Academy of Sciences he participated actively in the creation of a series of Institutes: Radium, Ceramic, Aerial Survey, and others.

In 1930 he founded the Institutes of Mineralogy and Geochemistry which were later amalgamated to form the Lomonosov Institute of Geochemistry, Mineralogy and Crystallography, of which he was director until 1938, when it was merged with the Petrographic and Geological Institutes.

Alexander Fersman displayed prodigious capacity for hard work. He was also an untiring traveller. Scarcely a district of the Soviet Union may be found in which he did not conduct researches and made some discoveries of scientific value.

Many of his trips took him abroad—to Sweden, Norway, Italy, Germany, Mongolia, and other countries. He was personally acquainted with many foreign scientists and corresponded with them constantly.

During Great Patriotic War A. Fersman, despite ill health, unfolded feverish activities to aid the front and direct that work in the Geological—Geographical Department of the Academy which was planned to serve the Red Army.

For a number of years he was a Member of the Presidium of the Academy, Secretary of its Department for Mathematics and Natural Sciences, and Director of several institutes. His last hour found him at the post of Director of the Institute of Geological Sciences and Director of the Kirov Base on Kola Peninsula.

He devoted much attention to the publishing activities of the Academy, was at one time administrator of the Academy's Publishing House, edited several periodicals and the proceedings issued by the Lomonosov Institute of Geochemistry. His name is linked with the publication of such important works as «Nonmetallic Minerals», «Khibiny Apatites», «The Minerals of Khibiny», «The Minerals of the USSR», and others, which played a major rôle in the development of science and the tapping of mineral resources.

He has left a vast scientific heritage. More than 700 publications, among them a number of large monographs. The bulk of his work pertains to mineralogy and geochemistry, and with W. I. Vernadsky he is justly regarded as our greatest mineralogist and geochemist.

He has made many brilliant contributions to mineralogy, descriptive, genetic, regional and applied. Outstanding among them are his «Precious and Coloured Stones of Russia», «Research on Magnesium Silicates», «Pegmatites», «Colours of Minerals», and so on.

A prominent place in his work on mineralogy is held by the problem of genesis. He devoted particular attention to paragenesis of minerals and association of elements in various geochemical processes; these associations he connected with the physical-chemical conditions under which the minerals had been formed, and with the properties of their atoms.

Even greater are his contributions to geochemistry, a new science born of mineralogy and largely developed owing to his endeavour. One salient trait characterizing his work in this domain is that his outlook on issues was always broad and his scientific interests manifold.

He was active in all branches of geochemistry; some of them were initiated and developed by him. A series of his investigations were concerned with the frequency of elements. Well-known are his tables of Clarke numbers. He also contributed a great deal to the development of the theory of isomorphism, and raised it to a level corresponding to modern achievements in crystallochemistry. The principal statements of the theory were formulated by him with great simplicity and precision.

Fersman worked out the problem of concentration and dissemination of elements in the Earth's crust. He is also responsible for further progress in the theory of geochemical systems and co-centres, and pointed out new possible methods or prospecting, based on general geochemical ideas.

In a series of works published in recent years and particularly in the III volume of his «Geochemistry», Fersman evolved a new theory on the migration of elements. He proved that the order in which different minerals separate from a

molten mass or solution in the process of cooling is related, in the first place, to the energy of their crystalline lattice which is a function of valencies and ionic radii. To estimate the crystalline lattice energy of a mineral he proposed an original method based on the introduction of ionic energy coefficients (ec's).

His profound theoretic investigations were ably combined with attempts to solve definite practical problems. This dual aim he had always in mind whether engaged in an expedition, or absorbed in theoretical research in his library.

Fersman is well-known as a gifted interpreter of scientific ideas to the broad public, and he was a master of pointed phrase in speech and in writing. His numerous reports before varied audiences, his popular books, notably, his «Fascinating Mineralogy» and «My Reminiscences of Stones», have contributed largely to the general interest in geochemistry and mineralogy among Soviet readers.

In 1943 Fersman received the Stalin prize first class for his outstanding contribution to science. The Soviet Government also conferred upon him the Order of the Red Banner. In 1943 he was awarded the Wollaston palladium medal by the London Geological Society, which is the highest distinction for research in geology.

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MATHEMATICS

A CONTRIBUTION TO THE THEORY OF DIRECT DECOMPOSITIONS OF TOPOLOGICAL GROUPS

By N. J. VILENKIN

(Communicated by A. N. Kolmogoroff, Member of the Academy, 13.X.1944)

§ 1. In the present paper we give the definition of the direct sum of an enumerable set of locally compact Abelian groups with the second countability axiom* possessing the compact component of the null-element**.

We apply this definition to zero-dimensional groups of type L***, and establish necessary and sufficient conditions for representability of such groups as direct sums of finite cyclic groups, groups of type p^∞ (2), groups of integral p-adic numbers and groups of rational p-adic numbers.

§ 2. Definition 1. Let $M=\{G_1; G_2; \ldots; G_n; \ldots\}$ be an enumerable set of groups of type LKK. Suppose that an open compact subgroup H_i is fixed in every $G_i (i=1, 2, \ldots, n, \ldots)$****. We shall define a group G that will be called *direct sum of group G_i with the subgroups H_i distinguished* (notation: $G=\sum_{i=1}^{\infty}\{G_i; H_i\}$). G will be supposed to consist of the sequences $x=\{x_1; x_2; \ldots; x_n; \ldots\}$ for which all $x_i \in G_i$ and almost all $x_i \in H_i$ (3). By the sum of the elements $x=\{x_1; x_2; \ldots; x_n; \ldots\}$ and $y=\{y_1; y_2; \ldots; y_n; \ldots\}$ we mean $x+y=\{x_1+y_1; x_2+y_2; \ldots; x_n+y_n; \ldots\}$; by the element opposite to $x=\{x_1; x_2; \ldots; x_n; \ldots\}$ we mean $-x=\{-x_1; -x_2; \ldots; -x_n; \ldots\}$. It is easily seen that G with the operation so defined is a group.

We now define neighbourhoods of the null-element in G. Let $U_1; U_2; \ldots; U_r$ be an arbitrary finite system of neighbourhoods of the null-elements in the groups $G_1; G_2; \ldots; G_r$. Then under the neighbourhood $U(U_1; U_2; \ldots U_r)$ of the null-element in G we understand the set of the elements $x=\{x_1; x_2; \ldots$ $\ldots x_n; \ldots\}$ such that $x_i \in U_i$ $(i \leqslant r)$ and $x_j \in H_j$ for $j > r$.

The totality of such neighbourhoods satisfies the five Pontrjagin conditions (1) and therefore can be considered as a complete system of neighbourhoods of the null-element in the group G.

Theorem 1. *The group G just constructed is a group of the type LKK.*

Definition 2. Suppose G is a group of type LKK, H is an open compact subgroup and $M=\{G_1; G_2; \ldots; G_n; \ldots\}$ is an enumerable set of sub-

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* These groups will be called groups of type L throughout the paper.
** Such groups will be called groups of type LKK.
*** Groups of type NL, as we call them here.
**** Any group of type LKK possesses an open compact subgroup.

groups of G. We say that *the group G with a subgroup H distinguished is decomposed into direct sum of the set M of its subgroups* (notation: $G:H=\sum_{i=1}^{\infty} G_i$) if the following conditions are fulfilled.

1. The minimal subgroup of the group G containing all the subgroups G_n of the set M coincides with G.

2. H is direct sum of its intersections with G_i, $H=\sum_{i=1}^{\infty}(G_i \frown H)$.

3. If $T_n (n=1, 2, 3, \ldots, l, \ldots)$ denotes the least subgroup G containing all G_i with the exception of G_n, then $\prod_{n=1}^{\infty} T_n = 0$.

Henceforth all the groups considered are of type *LKK*.

Theorem 2. *Let* $G=\sum_{i=1}^{\infty}(G_i:H_i)$. *Suppose* H *is the set of elements* $x=\{x_1; x_2; \ldots; x_n; \ldots\}$ *such that all* $x_i \in H_i$; G_i *is the set of elements with* $x_j=0_j$, $j \neq i$, *where* 0_j *is the null-element of* G_j. *Then* $G:H=\sum_{i=1}^{\infty} G_i$.

Theorem 3. *Let* $G:H=\sum_{i=1}^{\infty} G_i$. *Suppose* G_i' *are isomorphic to* G_i *and* H_i *are the subgroups of* G_i' *corresponding to* $G_i \frown H$ *under these isomorphisms* $(i=1, 2, \ldots)$. *Then* G *is isomorphic to* $G'=\sum_{i=1}^{\infty}\{G_i':H_i'\}$.

Theorem 4. *Suppose* $G=\sum_{i=1}^{\infty}\{G_i:H_i\}$, $G'=\sum_{1}^{\infty}\{G_i':H_i'\}$, *and for almost all* i $H_i \sim H_i'$ *under these isomorphisms. Then* $G \sim G'$.

§ 3. Let us apply the notion of direct sum to the theory of groups of type *NL*.

Definition 3. A group G of type *NL* in said to be topologically periodic if the subgroup generated by anyone of its elements is compact.

Definition 4. A group G of type *NL* is said to be topologically primary with respect to a prime p if $\lim_{n\to\infty} p^n x = 0$ for every $x \in G$.

Note that a topologically primary group is necessarily topologically periodic, and that a group G of type *NL* cannot be topologically primary with respect to different primes.

Theorem 5. *Every topologically periodic group G of type NL with an arbitrary subgroup H distinguished is decomposed into direct sum of topologically primary groups of the same type.*

In what follows all the groups considered will be supposed to be topologically primary with respect to a prime p.

Introduce the following notations: ${}_i(A)$ denotes the set of elements $x \in A$ such that $p^i x = 0$ («the i-th layer of A»); $p^n A$ denotes the set of elements of the form $p^n x$ where $x \in A$.

Definition 5. An element $x \in G$ is of topological height n if $x \in \overline{p^n G} \setminus \overline{p^{n+1} G}$. If $x \in \prod_{n=1}^{\infty} \overline{p^n G}$, then x is of infinite topological height.

Theorem 6. *A group G with an arbitrary open compact subgroup H distinguished can be decomposed into direct sum of cyclic subgroups if and only if*:

1) *G contains no elements of infinite topological height*;

2) *the set of elements of finite order is everywhere dense in G*;

3) $p^k H \frown p^n G = p^k [H \frown p^{n-k} G]$ *for every n and k; $k < n$; $n > 0$*;

4) $p^k G \frown \overline{p^{n+k} G} = p^k [\overline{p^n G}]$;

5) ${}_i[\overline{p^n G}] = \overline{{}_i[p^n G]}$ *for every $i = 1, 2, \ldots, t \ldots$, and for every n and k.*

Theorem 7. *A group G with an arbitrary open compact subgroup H distinguished can be decomposed into direct sum of groups of p-adic integral numbers if and only if*:

1) *G contains no elements of infinite topological height*;

2) *G contains no elements of finite order*;

3) $p^k G \frown \overline{p^{n+k} G} = \overline{p^k [p^n G]}$ *for every $n > 0$ and $k > 0$.*

Theorem 8. *A group G with an arbitrary open compact subgroup H distinguished can be decomposed into direct sum of groups of type p^∞ if and only if*:

1) *the set of elements of finite order is everywhere dense in G*;

2) *the set of elements of infinite topological height is everywhere dense in G*;

3) ${}_i(\overline{p^\infty G}) = \overline{{}_i(p^\infty G)}$ *for every $i > 0$.*

Theorem 9. *A group G with an arbitrary open compact subgroup H distinguished can be decomposed into direct sum of groups of rational p-adic numbers if and only if*:

1) *all elements of G are of infinite order*;

2) *the set of elements of infinite topological height is everywhere dense in G.*

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MATHEMATICS

ON A CLASS OF INTEGRAL EQUATIONS WITH A VARIABLE DOMAIN OF INTEGRATION

By V. M. DUBROVSKY

(Communicated by A. N. Kolmogoroff, Member of the Academy, 19.X.1944)

The aim of the present paper is to investigate the integral equation of the form

$$u(x) = f(x) + \lambda \int_{-\infty}^{x+h} K(x, y)\, u(y)\, dy \tag{1}$$

where λ and h are constants $(h > 0)$, and also to study the variation of its properties with vanishing h. The results are of importance for some problems of physics.

Theorem 1. *Let the nucleus $K(x, y)$ be real and defined in the domain $-\infty < x < +\infty$, $-\infty < y \leqslant x + h$, and suppose that for every fixed value of one of the variables x and y the nucleus is a measurable function of the other variable. Let the integral*

$$\Phi(x) = \int_{-\infty}^{x} L(y)\, dy$$

where $L(y)$ denotes the (finite or infinite) upper bound of $|K(x, y)|$ for x varying in the domain $y - h \leqslant x < +\infty$, and is finite for any finite x. Let the upper bound $H = H(h)$ of the difference $\Phi(x+h) - \Phi(x)$ that corresponds to all x, tend to zero for $h \to 0$. Let the function $f(x)$ be defined for all real x, and let it be real and measurable. Let, moreover, the integral

$$I(x, f) = \int_{-\infty}^{x} L(y)\, |f(y)|\, dy$$

be finite for any finite x, and $I(+\infty, f) \neq 0$. Let, finally

$$\operatorname*{Lim}_{x \to +\infty} \frac{I(x+h, f)}{I(x, f)} = 1 \tag{2}$$

Then the integral equation (1), where λ and h are constants $(h > 0)$, has a solution under the condition

$$|\lambda| < \frac{1}{H(h)\, e} \tag{3}$$

This solution is given by the series

$$u(x) = \sum_{n=0}^{\infty} u_n(x) \tag{4}$$

$$u_0(x) = f(x), \quad u_n(x) = \lambda \int_{-\infty}^{x+h} K(x, y)\, u_{n-1}(y)\, dy, \quad (n = 1, 2, \ldots) \tag{5}$$

If the condition (3) *is satisfied, there exists no other function* $u(x)$ *satisfying the equation* (1) *and enjoying the same properties with the function* $f(x)$.

Remark. The assumptions made concerning the nucleus $K(x, y)$ and the function $f(x)$ are quite general. The assumption that $H(h)$ vanishes with h is fulfilled, for instance, if either the integral $\Phi(+\infty)$ is finite or the nucleus $K(x, y)$ is bounded. The condition (2) is satisfied, if the integral $I(+\infty, f)$ is finite. Taking into account the finiteness of $H(h)$, it may as well be easily seen that condition (2) is also satisfied, if the function $f(x)$ is bounded.

Let us prove that (4) is a solution of (1).

The functions (5) are measurable and satisfy the inequalities

$$u_n(x) \leqslant |\lambda|^n \frac{1}{(n-1)!} I(x+nh, f)[\Phi(x)+(n-1)H]^{n-1} = U_n(x, f) \qquad (6)$$

where $n = 1, 2, \ldots$. In fact, the estimation (6) is evident for $n = 1$ and for $n = 2$. Assume now that this estimation holds for some natural n, and let us show that it remains valid when n is replaced by $n+1$. By (5) and (6) we obtain

$$|u_{n+1}(x)| \leqslant \frac{|\lambda|^{n+1}}{(n-1)!} I[x+(n+1)h, f] \int_{-\infty}^{x+h} L(y)[\Phi(y)+(n-1)H]^{n-1} dy$$

whence, taking an increasing sequence of numbers $y_0 = -\infty$, $y_1, y_2, \ldots, x_m = x+h$, we shall have

$$u_{n+1}(x)| \leqslant \frac{|\lambda|^{n+1}}{(n-1)!} I[x+(n+1)h, f] \sum_{i=1}^{m} [\Phi(y_i)+(n-1)] H^{n-1} \int_{y_{i-1}}^{y_i} L(y) dy$$

Since

$$\Phi(y_i) = \sum_{\nu=1}^{\nu=i} \int_{y_{\nu-1}}^{y_\nu} L(y) dy$$

$(i = 1, 2, \ldots, m)$, the last inequality in the limit, when $m \to \infty$ and all integrals $\int_{y_{i-1}}^{y_i} L(y) dy$ tend to zero, gives

$$|u_{n+1}(x) \leqslant \frac{|\lambda|^{n+1}}{(n-1)!} I[x+(n+1)h, f] \int_0^{\Phi(x+h)} [t+(n-1)H]^{n-1} dt$$

whence it can easily be deduced that the estimate (6) is also valid when n is replaced by $n+1$, q. e. d.

In view of the condition (2) we conclude without difficulty that the following equality holds:

$$\lim_{n\to\infty} \frac{U_{n+1}(x, f)}{U_n(x, f)} = |\lambda| H(h) e \qquad (7)$$

Thus, under the condition (3) the series (4) converges absolutely and uniformly in the domain $-\infty < x \leqslant x_0$, regardless of the value of x_0. Summing up the equalities (5) for $n = 1, 2, \ldots$, we see that the sum of the series (4) is in fact a solution of the equation (1).

That this solution is unique can be proved as follows.

Let the function $v(x)$ satisfy the equation (1) under the condition (3) and possess the same properties as the function $f(x)$. Putting

$$v_0(x) = v(x), \quad v_{n+1}(x) = \lambda \int_{-\infty}^{x+h} K(x, y) v_n(y) dy \qquad (8)$$

$(n=0, 1, 2, \ldots)$ and using the induction method, we easily verify that

$$v(x)=\sum_{k=0}^{n-1} u_k(x)+v_n(x) \tag{9}$$

$(n=1, 2, \ldots)$. As before, it follows from (8) that

$$|v_n(x)|\leqslant U_n(x, v) \tag{10}$$

$(n=1, 2 \ldots)$. Since for n tending to infinity the ratio of $U_{n+1}(x, v)$ to $U_n(x, v)$ tends to a limit that is less than one, the $U_n(x, v)$ and accordingly the $v_n(x)$ are vanishing, and so, in virtue of (9), $v(x)$ is identically equal to the sum of the series (4).

Remark. The preceding theorem evidently remains valid when $I(+\infty, f)=0$, and the other conditions, except (2), are satisfied. In this case the solution of the equation (1), which is unique under the condition (3), is given, as may be easily seen, by the function $u(x)$ identically equal to $f(x)$.

Theorem 2. *Let the function $K(x, y)$ be defined for $x\leqslant A$, $y\leqslant A$, equal to zero in the domain $x<A-h$, $x+h<y\leqslant A\,(h>0)$, real and measurable with respect to any of the variables x and y for every fixed value of the other variable. Let the function $f(x)$ be defined, real and measurable for $x\leqslant A$. Let the integrals*

$$\Phi(x)=\int_{-\infty}^{x} L(y)\,dy, \quad I(x, f)=\int_{-\infty}^{x} L(y)\,|f(y)|\,dy$$

be finite for $x\leqslant A$, where $L(y)$ is the (finite or infinite) upper bound of $|K(x, y)|$ for all x from the domain $y-h\leqslant x\leqslant A$. Then the integral equation

$$u(x)=f(x)+\lambda\int_{-\infty}^{A} K(x, y)\,u(y)\,dy \tag{11}$$

where λ is a constant parameter, has a unique solution determined for $x\leqslant A$ and satisfying the condition of finiteness of the integral $I(A, u)$ if

$$|\lambda|<\frac{1}{H(h)\,e} \tag{12}$$

where $H(h)$ denotes the upper bound of the difference $\Phi(x+h)-\Phi(x)$ for all $x\leqslant A-h$.

Proof. This theorem may be reduced to the preceding one, if we define the nucleus $K(x, y)$ and the function $f(x)$ in the domains in which they were defined in the preceding theorem, by putting $K(x, y)$ equal to zero in the domain $A-h<x\leqslant A$, $A<y\leqslant x+h$. It may be easily seen that the method of defining the functions $K(x, y)$ and $f(x)$ for $x>A$ is essential only so far as the conditions of Theorem 1 should be satisfied and the quantity $H(h)$ remain unaltered.

Remark. If in the case of Theorem 1 or Theorem 2 the nucleus $K(x, y)$ is continuous in x for some value of x and for arbitrary y, and the function $f(x)$ is continuous at the same value of x, then, as it follows from the assumptions concerning the nucleus, the function $u(x)$ satisfying the corresponding integral equation is also continuous at this value of x.

In conclusion it may be pointed out that for h tending to zero the right-hand sides of the inequalities (3) and (12) increase infinitely. We have here, as it were, a «continuous transition» to the properties of Volterra's equations.

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MATHÉMATIQUES

SUR LES CHAINES DE MARKOFF À UNE INFINITÉ DÉNOMBRABLE D'ÉTATS POSSIBLES

Par T. A. SARYMSAKOV, de l'Académie des Sciences d'Uzbekistan

Soient

$$E_1, E_2, \ldots, E_n, \ldots \tag{1}$$

les états possibles d'un certain système S. Désignons par p_{ij} and $p_{ij}^{(k)}$ les probabilités du passage de l'état E_i à l'état E_j au cours d'une et, respectivement, de k expériences; ces probabilités sont assujetties auxc onditions que l'on impose habituellement dans la théorie des chaînes de Markoff, à savoir

$$\left.\begin{aligned} p_{ij} &\geqslant 0, \quad \sum_j p_{ij} = 1 \\ p_{ij}^{(k)} &\geqslant 0, \quad \sum_j p_{ij}^{(k)} = 1 \end{aligned}\right\} \quad i, j = 1, 2, 3, \ldots$$

La matrice infinie $\Phi = \| p_{ij} \|$ sera nommée matrice du système S.

Désignons par S_n le système admettant les états

$$E_1, E_2, \ldots E_n, E_{\omega_n} \tag{2}$$

où

$$E_{\omega_n} = \sum_{j=1}^{\infty} E_{n+j}$$

Considérons d'ailleurs la matrice stochastique suivante*:

$${}^{\mu}\Omega_n = \begin{bmatrix} p_{11} & p_{12} \cdots p_{1n} & p_{1\omega_n} \\ \cdots & \cdots & \cdots \\ p_{n1} & p_{n2} \cdots p_{nn} & p_{n\omega_\mu} \\ {}^{\mu}p_{\omega_n 1} & {}^{\mu}p_{\omega_n 2} \cdots {}^{\mu}p_{\omega_n n} & {}^{\mu}p_{\omega_n \omega_n} \end{bmatrix}$$

Fixons dans la matrice ${}^{\mu}\Omega_n$ l'indice μ et en faisant n parcourir les valeurs 1, 2, 3, ... construisons une suite de matrices stochastiques

$$\Omega_1, \Omega_2, \ldots, \Omega_n \ldots, \tag{3}$$

où l'indice μ est omis pour abréger.

$p_{i\omega_n} (i = \overline{1, n})$ désigne la probabilité du passage de l'état E_i à l'état E_{ω_n} pendant une seule expérience, etc.; comme il est facile à vérifier, elle ne dépend pas de l'indice de cette expérience.

La quantité ${}^{\mu}p_{\omega_n i}$ désigne la probabilité du passage de l'état E_{ω_n} à l'état E pendant une seule expérience, à savoir de l'expérience d'indice $\mu - 1$ à l'expérience d'indice μ.

* La définition d'une matrice stochastique a été donnée dans ma Note[5]. Les autres notions que nous employons ici se trouvent dans la même Note.

Il suit des égalités évidentes

$$ {}^{\mu}p_{\omega_n i} = \frac{\sum_{j=n+1}^{\infty} p_{\mu-1\,|\,j}\, p_{ij}}{\sum_{j=n+1}^{\infty} p_{\mu-1\,|\,j}}, \quad {}^{\mu}p_{\omega_n \omega_n} = \frac{\sum_{j=n+1}^{\infty} p_{\mu-1\,|\,j}\left(\sum_{\sigma=n+1}^{\infty} p_{j\sigma}\right)}{\sum_{j=n+1}^{\infty} p_{\mu-1\,|\,j}}, \quad \mu = 1, 2, 3, \ldots $$

où $p_{\mu|j}$ est la probabilité absolue de l'état E_j dans l'expérience d'indice μ, que les éléments de la dernière ligne de la matrice ${}^{\mu}\Omega_n$ dépendent, en général, de l'indice de l'expérience. Il faut encore expliquer quel est le sens des probabilités considérées dans le cas où $\sum_{j=n+1}^{\infty} p_{\mu-1|j} = 0$, ce qui équivaut au système à une infinité d'égalités $p_{\mu-1|j} = 0$, $i = n+1, n+2, \ldots$

Dans ce cas dans l'expérience d'indice $\mu - 1$ l'état E_j est impossible si $j \geqslant n+1$, donc il est aussi impossible de passer de l'état E_{ω_n} en un autre état quelconque dans l'expérience d'indice μ. Dans ce cas les probabilités ${}^{\mu}p_{\omega_n n}\,(i = \overline{1, n})$ et $p_{\omega_n \omega_n}$ seront considérées comme nulles.

On sait qu'une méthode effective et habituelle pour étudier les chaînes de Markoff à un nombre fini d'états possibles, c'est la méthode des matrices étudiée d'une manière détaillée par Romanovsky [1]. En faisant un passage à la limite, on peut démontrer que l'étude des chaînes de Markoff à une infinité dénombrable d'états possibles (1) peut être réduite à l'étude des chaînes de Markoff à un nombre fini d'états (2), c'est-à-dire à l'étude des matrices des systèmes S_n et de leurs suites. En particulier, au moyen de cette méthode plusieurs résultats de l'article cité de Romanovsky concernant les chaînes de Markoff à un nombre fini d'états possibles peuvent être étendus au cas des chaînes à une infinité dénombrable d'états possibles. Comme exemple, énonçons les propositions suivantes:

Théorème 1. *Si une suite de matrices stochastiques* (3) *est primitive et le nombre* $\lambda_0 = 1$ *est une racine simple de l'équation* $\Omega_n(\lambda) = 0$ *pour chaque valeur de n, alors il existe une limite de* $p_{ij}^{(k)}$ *pour* $k \to \infty$; *cette limite ne dépend pas de i et elle est définie par la formule*

$$ \lim_{k\to\infty} p_{ij}^{(k)} = \lim_{n\to\infty} \frac{\Omega_{n\,jj}(1)}{\Omega_n'(1)} = p_j^{*} \qquad (4) $$

si la limite par rapport à n existe.

Théorème 2. *Pour que les égalités*

$$ \lim_{k\to\infty} p_{ij}^{(k)} = p_j \geqslant 0 \quad \textit{pour} \quad j = \overline{1, m};\ i = 1, 2, 3, \ldots $$

$$ \lim_{k\to\infty} p_{ij}^{(k)} = 0 \quad \textit{pour} \quad j = m+1, m+2, \ldots;\ i = 1, 2, 3, \ldots $$

aient lieu, il faut et il suffit que la matrice infinie Φ *soit de la forme*

$$ \Phi = \begin{pmatrix} P & 0 \\ Q & R \end{pmatrix} $$

où P est une matrice primitive d'ordre m, dont $\lambda_0 = 1$ *est une racine simple.*

Introduisons la définition suivante:

Une chaîne de Markoff est nommée régulière si la limite $\lim_{k\to\infty} p_{ij}^{(k)} \quad p_j$ existe et ne dépend pas de i. Si $p_j > 0$ pour toutes les valeurs de j, la chaîne est nommée positivement régulière.

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* Il faut remarquer qu'on n'a pas toujours $\sum_{j=1}^{\infty} p_j = 1$; pour que cela ait lieu il faut que $\lim_{n\to\infty} \Omega_n'(1) < +\infty$, ce qui n'est pas toujours possible.

Dans les conditions du théorème 1 pour la régularité positive il est nécessaire et suffisant que la limite

$$\lim_{n\to\infty} \frac{\Omega_{n|jj}(1)}{\sum_{\alpha=1}^{\omega_n} \Omega_{n|\alpha\alpha}(1)} = \lim_{n\to\infty} \frac{\Omega_{n|jj}(1)}{\Omega'_n 1}$$

existe et soit positive pour $j = 1, 2, 3, \ldots$

Comme exemple d'une chaîne régulière et d'ailleurs positive on peut indiquer un jeu étudié par Bernstein (2). En associant aux expériences les variables aléatoires $\xi_1, \xi_2, \ldots, \xi_n, \ldots$ dont les valeurs possibles sont égales aux nombres réels $x_1, x_2, \ldots, x_i, \ldots$, et en supposant que ξ_n prend la valeur x_i, si le système S passe dans le n-ième pas dans l'état E_i, étudions le problème sur la loi de distribution limite. A cet effet considérons non seulement les matrices Φ et Ω_n, mais encore les matrices

$$\mathrm{Mt}\,\Phi(\theta) = \| p_{kj} e^{i\theta(x_j - a)} \| \quad (k, j = 1, 2, 3, \ldots)$$

et

$$\mathrm{Mt}\,\Omega_n(\theta) = \begin{pmatrix} p_{11}e^{i\theta(x_1-a_n)} \ldots p_{1n}e^{i\theta(x_n-a_n)}\, p_{1\omega_n}e^{i\theta(x_{\omega_n}-a_n)} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ p_{n1}e^{i\theta(x_1-a_n)} \ldots p_{nn}e^{i\theta(x_n-a_n)}\, p_{n\omega_n}e^{i\theta(x_{\omega_n}-a_n)} \\ p_{\omega_n 1}e^{i\theta(x_1-a_n)} \ldots p_{\omega_n n}e^{i\theta(x_n-a_n)}\, p_{\omega_n\omega_n}e^{i\theta(x_{\omega_n}-a_n)} \end{pmatrix}$$

où $a = \lim_{n\to\infty} a_n$, si cette limite existe;

$$a_n = \left[\sum_{\alpha=1}^{\omega_n} x_\alpha \Omega_{n|\alpha\alpha}(1)\right] : \left[\sum_{\alpha=1}^{\omega_n} \Omega_{n|\alpha\alpha}(1)\right]$$

$\Omega_{n\,\alpha\alpha}(1)$ est le mineur du déterminant $\Omega_n(1)$, correspondant à l'élément de la α-ième ligne et de la α-ième colonne, et enfin $x_{\omega_n} = x_{n+1}$.

Construisons maintenant l'équation caractéristique $\Omega_n(\lambda, \theta) = 0$ qui correspond à la matrice $\mathrm{Mt}\,\Omega_n(\theta)$, et désignons par $\lambda_0^{(n)}(\theta)$ sa racine qui pour $\theta = 0$ se transforme en racine $\lambda_0^{(n)}(0) = 1$ de l'équation $\Omega_n(\lambda) = 0$. Il est facile à voir que $\Omega_n(\lambda, 0) = \Omega_n(\lambda)$.

Désignons par $\lambda_0''(0)$ la limite

$$\lim_{n\to\infty} \left.\frac{d^2\lambda_0^{(n)}(\theta)}{d\theta^2}\right|_{\theta=0}$$

(pourvu qu'elle existe).

On a alors la proposition suivante:

Théorème 3. *Si les constantes a et $\lambda_0''(0) \neq 0$, précédemment définies, existent, alors pour que l'égalité limite*

$$\lim_{k\to\infty} P\left(\alpha < \frac{\xi_1 + \xi_2 + \ldots + \xi_k - ka}{\sqrt{-k\lambda_0''(0)}} < \beta\right) = \frac{1}{\sqrt{2\pi}} \int_\alpha^\beta e^{-\frac{1}{2}t^2}\, dt$$

ait lieu, il faut et il suffit que la suite (3) *des matrices stochastiques soit primitive et indécomposable à partir d'un certain membre.*

Les résultats des théorèmes 1, 2 et 3 ont été obtenus dans des conditions différentes et par des méthodes différentes par Kolmogoroff (3) et Doeblin (4).

Université d'Asie Centrale
à Tachkent.

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MATHEMATICS

THE DIFFERENTIAL PROPERTIES OF FUNCTIONS WITH ONE NON-NEGATIVE FINITE DIFFERENCE OF ORDER n

By I. CHLODOVSKY

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1. Credit for being the first to make a systematic inquiry into the properties of functions with a non-negative difference belongs to Jensen [1]. He studied the properties of convex functions, *i. e.* of functions with a non-negative second finite difference. Further progress in the investigation of this problem is due to Bernstein [2,3], who gave a comprehensive characteristic of the differential properties of functions on the assumption that all its finite differences up to a certain order are non-negative.

The present note is devoted to the study of differential properties of a function when its finite difference of the order n a l o n e does not change sign in a certain segment. For the sake of definiteness we shall suppose that this finite difference is non-negative. With obvious modifications all of the results formulated below will also hold for functions with a non-positive finite difference of the given order.

2. T h e o r e m 1. *If the function $f(x)$ is bounded in the segment $[a, b]$ and its finite difference of the order n $(n \geqslant 2)$ is non-negative in this segment, then the function $f(x)$ is continuous in the interval (a, b).*

From the fact that $\Delta^n f(x) \geqslant 0$ in the segment $[a, b]$ and from the boundedness of $f(x)$ follows that for any fixed x $(a < x < b)$ and an arbitrary natural p we have:

$$\overline{\lim_{n\to 0}}_{h} \Delta^{n-1} f(x+ph) \leqslant 0, \quad \lim_{h\to 0}{}_{h} \Delta^{n-1} f(x+ph) \geqslant 0$$

Combining these inequalities we find

$$\lim_{h\to 0}{}_{h} \Delta^{n-1} f(x+ph) = 0$$

This equality enables us to show that the following equality will also hold:

$$\lim_{h\to 0}{}_{h} \Delta^{n-2} f(x+ph) = 0, \quad n \geqslant 3$$

q. e. d.

3. R e m a r k. The condition of boundedness of $f(x)$ may be replaced by any equivalent condition. It will suffice to require that $f(x)$ be finite at every point of $[a, b]$, and measurable.

4. Let us denote by $p_k(x; x_0, h)$ the interpolation polynomial of degree k coinciding with $f(x)$ at the points $x_0, x_0+h, \ldots x_0+kh$.

Jensen's theorem on the convexity of functions with a non-negative second difference may be generalized as follows:

Theorem 2. *If the function $f(x)$ is bounded in the segment $[a, b]$ and $\Delta_h^n f(x) \geqslant 0$, then either the inequalities*

$$(-1)^k [f(x) - p_{n-1}(x; x_0, h)] > 0, \quad x_0 + \overline{k-1}h < x < x_0 + kh$$

for $n = 2p$, and

$$(-1)^k [f(x) - p_{n-1}(x; x_0, h)] < 0, \quad x_0 + \overline{k-1}h < x < x_0 + kh$$

for $n = 2p+1$, where $k = 1, 2, \ldots, n$, hold, or

$$f(x) \equiv p_{n-1}(x; x_0, h)$$

in $a < x_0 \leqslant x \leqslant x_0 + nh \leqslant b$.

This theorem may be easily proved by means of Newton's interpolation formula with the remainder term in the following form:

$$f(x) - p_{n-1}(x; x_0, h) = \frac{\Delta_h^n f(\xi)}{h^n n!} (x - x_0)(x - x_1) \ldots (x - x_{n-1})$$

This form of the remainder term was for the first time applied by Bernstein (2).

Principal Theorem. *If the function $f(x)$ is bounded in every segment situated inside the interval (a, b), and in this interval its finite difference of the order $n (n \geqslant 2)$ is non-negative, then the function $f(x)$ and its $n-2$ first derivatives are absolutely continuous in the interval (a, b), and there is also a right and a left derivative of the order $n-1$, both of them non-decreasing and continuous from the right and from the left, respectively.*

The proof proceeds on the following lines.

First of all the following inequalities can be established by means of Theorems 1 and 2:

$$\frac{\Delta_\delta^{n-1} f(x)}{\delta^{n-1}} < \frac{\Delta_h^{n-1} f(x)}{h^{n-1}}, \quad \text{or} \quad \frac{\Delta_\delta^{n-1} f(x)}{\delta^{n-1}} \equiv \frac{\Delta_h^{n-1} f(x)}{h^{n-1}}, \quad 0 < \delta < h \tag{1}$$

$$\frac{\Delta_\delta^{n-1} f(x - \overline{n-1}\delta)}{\delta^{n-1}} > \frac{\Delta_h^{n-1} f(x - \overline{n-1}h)}{h^{n-1}}$$

or

$$\frac{\Delta_\delta^{n-1} f(x - \overline{n-1}\delta)}{\delta^{n-1}} \equiv \frac{\Delta_h^{n-1} f(x - \overline{n-1}h)}{h^{n-1}}, \quad 0 < \delta < h \tag{2}$$

$$\Delta_h^{n-1} f(x) \leqslant \Delta_h^{n-1} f(x_1), \quad \text{if} \quad x_1 > x \tag{3}$$

From these inequalities follows the existence of functions

$$\lim_{h \to 0} \frac{\Delta_h^{n-1} f(x)}{h^{n-1}} = \Delta_{n-1}^{+}(x), \quad \lim_{h \to 0} \frac{\Delta_h^{n-1} f(x - \overline{n-1}h)}{h^{n-1}} = \Delta_{n-1}^{-}(x)$$

The first of these functions is not decreasing and continuous from the right, the second is not decreasing and continuous from the left, and the

values of both coincide at the points of continuity. A further consideration of the properties of the function $\Delta^{+}_{n-1}(x)$ and of its connexion with the function $f(x)$ shows that*

$$f=(x)\int_a^x\int_a^x\dots\int_a^x\Delta^{+}_{n-1}(x)(dx)^{n-1}+\text{a polynomial of degree } n-1 \qquad (4)$$

The equality (4) being established, to complete the proof of the theorem we have to show the existence of a right and a left derivative of order $(n-1)$. By (4) we have

$$\Delta^{+}_{n-1}(x)\leqslant\frac{f^{(n-2)}(x+h)-f^{(n-2)}(x)}{h}\leqslant\Delta^{+}_{n-1}(x+h)$$

whence

$$f^{+(n-1)}(x)=\Delta^{+}_{n-1}(x)$$

Similarly we prove that

$$f^{-(n-1)}(x)=\Delta^{-}_{n-1}(x)$$

q. e. d.

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* Generally speaking, $\Delta^{+}_{n-1}(x)$ does not determine the function $f(x)$, but if the difference of the order n of $f(x)$ is non-negative, then the function $f(x)$ is determined by $\Delta^{+}_{n-1}(x)$ up to an additive polynomial of degree $\leqslant n-1$.

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PHYSICS

REGISTRATION OF URANIUM FRAGMENTS WITH REMOVAL OF BACKGROUND DUE TO α-PARTICLES EMITTED BY URANIUM

By N. A. PERFILOV

(Communicated by V. G. Chlopin, Member of the Academy, 20.VII.1944)

In a previous paper we showed [1] that the action of the oxide of $K_3Fe(CN)_6$ in the presence of hyposulphite on the latent image produced in a photographic plate by *a*-particles leads to the destruction of centres of development produced by single excitation of the grains by the α-particles. Such grains consequently lose their property of selective developments while those grains which are excited 2, 3 *etc.* times develop normally.

We also pointed out the consequence which follows from this discovery. If one investigates by the photographic plate method a radiation consisting of alphas and particles of higher ionizing power per unit length, then by treating the photographic layer in the manner described above the excitation effect should be destroyed in the grains touched by the alphas, and only tracks of the heavier ionizing particles should develop.

In the present investigation this statement is proved by experiments in which the tracks of uranium fission fragments produced by neutrons are separated from the tracks of α-particles spontaneously emitted by the uranium atoms. As is well known from a number of investigations [2], the two uranium fission fragments caused by neutron bombardment possess a total energy of 160—170 MeV, which is divided among the fragments according to their masses and the law of conservation of momentum. The specific ionization loss of the fragments on traversing a medium exceeds 30—40 times that of α-particles. Thus, the silver bromide grains located on the path of the fissions will essentially differ in degree of excitation from the grains excited by α-particles, and treatment of the photographic layer before development should lead to separation of the fission tracks from those of the α-particles.

Experiments on Separation of Fission Tracks from α-particle Tracks. The experiments were made in the following way. A photographic plate was placed in a metallic plate-holder in which the air pressure was reduced to 1—2 mm Hg; at a distance of 1 mm from the plate was located a uniform layer of powder U_3O_8 which was precipitated on a brass plate. The plate-holder with the uranium sample and photographic plate was then irradiated by a beam of neutrons from RaTh + Be of about 200 mC intensity. A 9.5 cm layer of lead interposed between the plate-holder and source served as a screen from γ-rays. In order that the geometry of the source and photographic plate remain the same during measurements with slow neutrons (in presence of water) as that used during measurements with fast neutrons, the source, lead and plate-holder were placed in an iron tank 32 cm in diameter. After irradiation with fast neutrons during a period of 64 hours the photographic plate was removed

from the holder and was divided into two parts. One of these was developed without any further treatment. The second half was treated with a water solution of $K_3Fe(CN)_6$ of 1 : 5000 g/cm³ concentration and an equivalent amount of hyposulphite in the manner described above (1) and was then developed; this treatment served to destroy the latent image of the α-particle tracks prior to development.

As a control another plate was irradiated by α-particles from the same U_3O_8 source during 64 hours in the absence of the neutron source. The uranium sample was then removed, and over the same period of time the photographic plate was exposed to neutrons and γ-rays from the source, the geometrical conditions remaining identical with those of the test-plate. After irradiation the control plate was treated exactly as the test-plate was, and after development each of the plates were microscopically examined and compared.

On the test-plate which was treated prior to development with the aim of destroying the latent image of the α-tracks, some tracks were detected in the form of chains of developed grains which must necessarily be ascribed to the uranium fragments. In the majority of cases these tracks differ in outward appearance from those of the α-particles radiated by uranium or, say, polonium (if registered in the same emulsion) by the larger number of grains per unit path. Quite often near the end of the path, a change in direction occurs due to collisions with the nuclei of silver or bromine or any of the other elements comprising the gelatine.

Appearance of the so-called Δ-nuclei near the end of the tracks of the fragments has been especially well illustrated in investigation (3) carried out with a cloud chamber at 6.5 cm Hg pressure. It is impossible to detect tracks of the Δ-nuclei in the photographic layer after treatment, if the energy loss of the Δ-nuclei does not exceed that of the α-particles. In the case of high specific losses these nuclei can be detected only if their range exceeds 0.25 cm air equivalent. Smaller ranges lead to the result that only one grain may be excited, and even if this grain be developed, it might easily be ascribed to the background effect.

Thus, examination of the track may merely indicate a deflection of the fragment itself. The ratio of the maximum range of the fission particles to the path lengths of the α-particles from polonium turned out to be 0.53—0.6 in the emulsion, this being equivalent to about 2—2.3 cm of air.

In order to be completely certain that the detected tracks really belonged to uranium fragments, the experiment described above was repeated, the only difference now being that the tank was filled with water in order to slow down the neutrons. As is well known, the fission rate sharply increases if irradiation is carried out with slow neutrons, this being a result of fission of the uranium isotope of atomic weight 235. Thus, if only fission fragment tracks really remain after the treatment and development, their number should sharply rise in this case.

This asumption was confirmed by experiment, as can be seen from the accompanying table.

	Number of fragment tracks detected	Number of fragment tracks per 1 cm²
Control photo-plate	5	13
Irradiated with fast neutrons	47	110
Irradiated by slow neutrons	529	1390

It will be seen from the table that five tracks were also found on the control plate, although their appearance seems quite inexplicable. Not more than one of these tracks can be ascribed to the spontaneous fission of uranium (4). Most of these five tracks, however, consist of only 2—3 grains. Although their origin

may be accidental, we do not think it possible to disregard them, as in a 3 mg/cm² layer of uranium they could be the tracks of fragments which lost part of their range during traversal of the U_3O_8 layer itself. Application of thinner layers of U_3O_8 in the experiments would be inadvisable due to the weak intensity of the neutron source.

A result similar to the one we obtained in separation of the fragment tracks from those of the α-particles, can also be attained by acting on the latent image by oxides other than that of $K_3Fe(CN)_6$, for example, by using an aqueous solution of CrO_3. In this case no addition of hyposulphite is necessary. A suitable concentration for this purpose is 1 : 6500—1 : 7000 g/cm³. The results are similar to those obtained above.

Quantitative Check of Method. In order to estimate quantitatively the accuracy of the method and to be sure that not a part but all fragments incident on the photographic plate can be counted after treatment of the photo-layer, we determined the effective cross-section for fission of uranium when irradiated with fast neutrons.

In order to exclude the dependence on the number of neutrons it was convenient to use the well-known data on scattering of neutrons by protons [5], as hydrogen is a constituent of gelatine and the resulting recoil nuclei are recorded by the emulsion.

Let σ_1 be the cross-section for scattering of neutrons by protons, n_1 be the number of recoil nuclei tracks, and a_1, the number of hydrogen atoms. σ_2 is correspondingly the unknown cross-section; a_2, number of uranium atoms; and n_2, number of uranium fragments. All values are referred to a square centimetre of the surface of the photographic plate and the uranium sample.

Then

$$\sigma_2 = \sigma_1 \frac{n_2 a_1}{n_1 a_2}$$

The values of n_2 are given in the table. In order to determine n_1 the photographic plate was placed in the position in which the uranium sample was located during the experiments, and was then irradiated with the same neutron source. The number of recoil protons was then counted and was reduced to the same irradiation time as the time the fragment recording plate was irradiated (the reduced number equalled 4520 tracks/cm²). a_1 was calculated from the weight of the gelatine in the emulsion. Besides hydrogen atoms, 20 per cent of the total number of atoms * of O^{16}, N^{14} and C^{12} have been included in a_1.

It was assumed that 80 per cent of the collisions of neutrons with the atoms of three elements cannot be detected by their recoil nuclei due to the small range of the latter. This conclusion is based on the form of the neutron spectrum [6] produced by the Rn + Be source **, and on the energies transferred to the nuclei of elements of 16, 14 and 12 times larger mass. The calculated value is $a_1 = 24 \cdot 10^{19}$.

The value of a_2 should not exactly equal the total number of uranium atoms; account should be made for absorption in the layer itself. Assuming that 6 mg/cm² of U_3O_8 is the limiting layer *** for traversal of fragments, one may determine the value of a_2 from the formula:

$$a_2 = \frac{a_{02}}{n} \sum_{i=1}^{n} (1 - \cos \varphi_i)$$

where a_{02} is the number of uranium atoms per square centimetre of the sample, and φ_i is the limiting angle of exit of the fragments from the i layer. The cal-

* We have accepted here the following composition by weight for gelatine (or albumen): H = 7 per cent; C = 52.5 per cent; O = 21.5 per cent; N = 17 per cent; S = 2 per cent.

** The neutron spectrum from the RaTh + Be source was not investigated. One may think that it should be similar to the Rn + Be spectrum, differing, however, in the number of neutrons of energy 1 MeV, which should be somewhat larger due to higher energy of the α-particles.

*** According to the measurements of K. A. Petrjak and M. L. Orbeli (unpublished).

culated value is $a_2 = 0.486 \cdot 10^{19}$. After inserting in the formula for σ_2 all of these values and putting $\sigma_1 = 1.7 \cdot 10^{-24}$, cm^2 ([5]), we obtain $\sigma_2 = 0.2 \cdot 10^{-24}$ cm^2.

This value satisfactorily accords with the value $0.1 \cdot 10^{-24}$ cm^2 obtained previously by other investigators ([7]) for fast neutrons from the Rn + Be source. As a matter of fact, the RaTh + Be neutron source should yield a somewhat greater number of neutrons of energy, exceeding the threshold value necessary for fission of the main isotope, and therefore the value for σ should be somewhat larger. Furthermore, the accuracy of determination of σ for scattering of hydrogen, as well as the value of σ previously found for uranium, cannot be considered very high. Thus, it may be considered that the value obtained here exactly (within the accuracy of statistical errors) yields the number of fragments in accord with their number, incident on the photographic plate from the U_3O_8 layer.

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BIOPHYSICS

ABSOLUTE SENSITIVITY OF THE EYE IN INFRA-RED SPECTRUM

By N. I. PINEGIN

(Communicated by S. I. Wawilow, Member of the Academy, 11.IX.1944)

Different authors ([1-9]) have given different estimates of the limit of sensitivity of the normal eye in the infra-red spectrum. Apart from the rather arbitrary assertion of Nutting ([9]) that the eye is able to see radiations up to 1000 mμ in

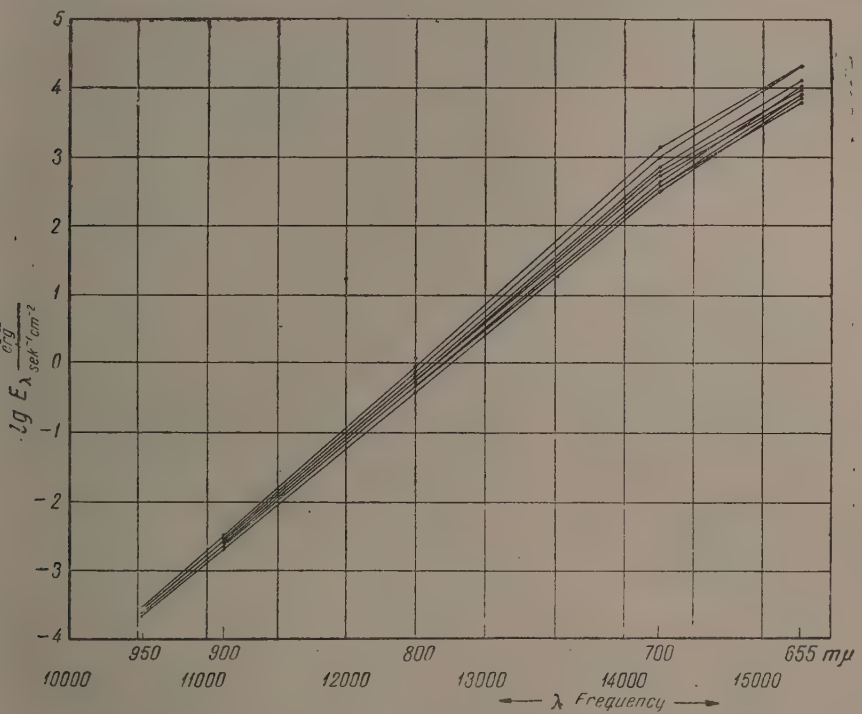

Fig. 1

wave-length, there is only one experimental investigation by Goodeve ([8]) who has measured the relative sensitivity of the eye up to 900 mμ on two observers. He has found that the logarithmic sensitivity curve, plotted against frequency-wave numbers, runs as a straight line in the region 700—900 mμ; for 900 mμ

Threshold Illumination of Cornea E^{λ} in erg/sec. cm². Exit Slit of Monochromator, 15×0.2 mm

λ, mμ	N. P.	K. B.	Z. E.	M. K.	N. N.	N. S.	N. B.	V. G.	V. M.	A. L.	U. Ch.	$E_{\lambda\,mean}$	—Log. E_{λ}
655	$5.17 \cdot 10^{-5}$	$4.91 \cdot 10^{-5}$	$1.19 \cdot 10^{-4}$	$1.16 \cdot 10^{-4}$	$7.75 \cdot 10^{-5}$	$1.47 \cdot 10^{-4}$	$1.01 \cdot 10^{-4}$	$1.22 \cdot 10^{-4}$	$1.24 \cdot 10^{-4}$	$1.37 \cdot 10^{-4}$	$5.17 \cdot 10^{-5}$	$9.94 \cdot 10^{-5}$	4.00
700	$9.75 \cdot 10^{-4}$	$8.05 \cdot 10^{-4}$	$1.91 \cdot 10^{-3}$	$1.64 \cdot 10^{-3}$	$1.39 \cdot 10^{-3}$	$2.51 \cdot 10^{-3}$	$2.34 \cdot 10^{-3}$	$2.24 \cdot 10^{-3}$	$2.5 \cdot 10^{-3}$	$3.26 \cdot 10^{-3}$	$7.8 \cdot 10^{-4}$	$1.85 \cdot 10^{-3}$	2.73
800	1.244	1.093	1.985	2.003	1.789	2.451	2.467	2.597	2.634	2.792	$9.09 \cdot 10^{-1}$	1.997	—0.30
900	356.2	317.7	464.2	403.3	345.7	317.2	507.0	376.7	459.2	500.4	305.6	395.8	—2.60
950	3884.6	—	3884.6	—	—	—	—	—	—	—	—	4077.4*	—3.61
951	—	—	—	—	—	3647.5	4427.7	4427.7	4427.7	—	—		
952	—	—	—	—	3917.5	—	—	—	—	4493.6	3687.0		
953	—	—	—	3952.0	—	—	—	—	—	—	—		
955	—	4101.8	—	—	—	—	—	—	—	—	—		

* Mean for $E_{650\ m\mu} - E_{955\ m\mu}$.

the sensitivity is 250 000 times lower than for 700 mμ. His data, however, give no ground for the assertion that $\lambda = 900$ mμ is the limit of the eye's sensitivity. From the extrapolation of his curve up to 950 mμ Goodeve arrived at the conclusion that the sensitivity to 950 mμ should be 10 times as small as to 900 mμ.

The present author has found it necessary to obtain additional experimental data on the absolute sensitivity of the eye in the red and infra-red. For spectral decomposition he used a glass monochromator in conjunction with red and infra-red glass filters which eliminated stray light from monochromatic radiation. The source of light was a tungsten lamp; the incandescence temperature of the filament was about 3 500°K. The monochromator was calibrated against the argon spectrum by means of an electronic optical transformer up to 9657.8 Å. Both the entrance slit and the exit slit of the monochromator were 0.2 mm wide. The purity of the spectrum in the region of 900 mμ was $\Delta\lambda = \pm 5$ mμ. The absolute energy distribution in the spectrum of the lamp was measured with a Zeiss([10]) thermopile graduated against the Hefner candle. The measurements were made after a dark adaptation interval of 30 minutes. For the test object the exit slit of the monochromator (15 × 0.2 mm) was used. It was viewed through an eye-piece with ×9 magnification and an exit pupil of 3.6 mm. Light losses in the eye-piece were estimated at 20 per cent.

Qualitative observations have revealed that in the argon spectrum (argon lamp for 5—8 ampères) the 8416.5 Å line is barely visible and appears to be red in colour. In the tungsten spectrum the sensitivity extended up to 950 mμ, and the radiation was likewise perceived as red; at the threshold visibility the radiation was an unsaturated red. Adaptation has an unmistakable influence on the sensitivity of the eye in the red and infra-red. Special experiments with adaptation, which will be reported elsewhere, have shown that in the region of 655—950 mμ the photopic vision is active.

Quantitative determinations were as follows. The absolute threshold sensitivity of the eye was measured in the region of 655—950 mμ on eleven observers with normal vision. Their colour vision was checked against Ishihara's table and was found to be normal, too, in all cases. The sensitivity of the eye was measured by the extinction method with the aid of a graphite photometrical wedge.

The results, expressed in terms of the threshold illumination at the cornea. $E_\lambda\left(\frac{\text{erg}}{\text{sec}.\text{cm}^3}\right)$, are given in the adjoined table and figures. In columns 2—12 of the table are listed the illumination values at the cornea for each observer separately; column 13 gives the mean values for all observers. In the figures the negative logarithms of E_λ are plotted against frequency-wave numbers. Fig. 1 represents individual curves, and Fig. 2 gives the mean curve for all observers.

It may be seen that all curves have a linear course in the region of 700—950 mμ. The individual curves (Fig. 1) converge more or less closely towards 950 mμ, where the sensitivity in the individual observers varies only as much as 1.2 times, and diverge slightly at 655 mμ, where the range of variation of the individual sensitivity is 3 times. It will be obvious that in the region of 655—950 mμ there is no considerable fluctuation in individual sensitivity.

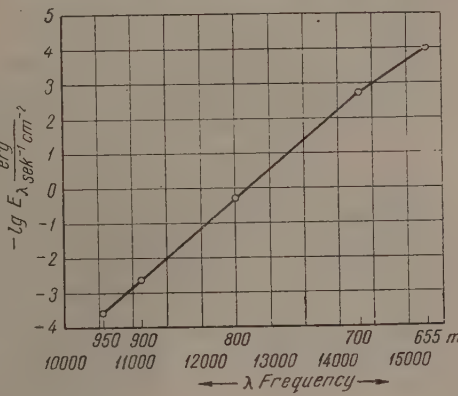

Fig. 2

Our data confirm those obtained by Goodeve, so far as the linear dependence between the negative logarithms of the threshold illumination at the cornea and the frequency-wave numbers in the infra-red spectrum is concerned. On the other hand, the ratio between the sensitivity to 700 mμ and to 900 mμ has been found in our experiments to be 214 000 as against 250 000 observed by Goodeve. Both values lie within the same order of magnitude. Also his assumption that the sensitivity to 950 mμ should be ten times less than to 900 mμ, has found confirmation in our experiments. Indeed, the sensitivity difference for 950 and 900 mμ proved to be 10.3 times as an average for 11 observers.

It may be pointed out in conclusion that the sensitivity to 900 mμ is, according to Goodeve, 60 000 000 times lower than the maximum sensitivity in the visible spectrum which corresponds to 555 mμ. If we are to compare the data presented here with those obtained previously in the region of 302—700 mμ ([10-11]), it will be apparent that the absolute sensitivity of the eye to 900 mμ is nearly 110 000 000 times less than to 546 mμ, which wave-length approaches closely that corresponding to the maximum sensitivity in the visible spectrum.

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The State Optical Institute.

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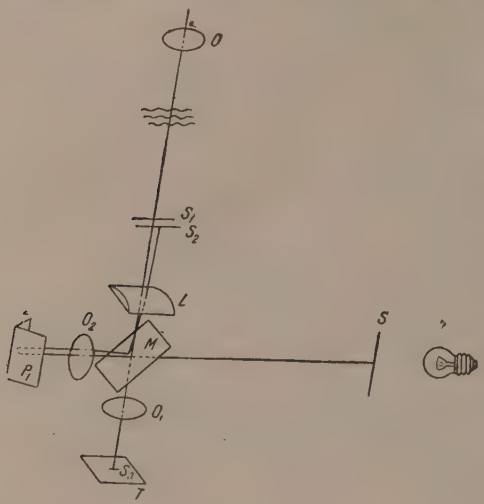
TECHNICAL PHYSICS

«MICRO-PROFILOMETER», A DEVICE FOR STUDYING THE MICRO-PROFILE OF SURFACES BY THE INTERFERENTIAL METHOD

By V. LINNIK, Member of the Academy

Decisions as to the qualities of a tooled surface can be based on the study of its micro-profile, which plays a vital rôle in the working processes of machine parts; particularly so when the surface concerned is to operate under friction. Immediate observation of surface profile is therefore a matter of great importance.



When the surface has been machined in parallel striae, this task is easily solved with the aid of a micro-interferometer, since the interferential bands, rendered visible by this apparatus, faithfully repeat, when perpendicular to the striae, the profile of the surface though in altered scale. In the case of a surface with irregularities of no definite form and with striae of no preferential orientation, the interferential pattern loses in clarity, grows complex and difficult to decipher.

By means of the following apparatus the micro-profile of any normal section of a surface can be observed directly, no matter how complex the structure of the surface may be.

Acting on the Fresnel principle, this «micro-profilometer» permits observation of micro-profiles by examining the ordinary interference pattern in white light, where the zero band is easily determined from the colour symmetry of the adjoining bands.

The rays beamed from the vertical slit S (see diagram) by some source of white light fall upon the semi-transparent mirror M. They are partially reflected from mirror M and, passing through the objective of microscope O_1, reproduce on object T the image S_3 of S. The rays then pass through mirror M and the cylindrical lens L, the axis of which lies in the plane of the diagram, and form the image S_1 of the slit S.

Part of the rays, having crossed the semi-transparent mirror M in a horizontal direction, pass through the second objective O_2 and attain the double mirror scheme of P_1 and P_2. Set at right angles, these mirrors reflect the shape of S

into the space between them. Reflected by P_1 and P_2 and returning through objective O_2, the rays beamed upward from mirror M and passing through the cylindrical lens L will produce a second image S_2 of S.

If the slit S is sufficiently narrow, the reflections S_1 and S_2 will emit coherent rays and, in the case of a flat object T, will yield an interferential pattern visible through the eye-piece O as in any of the Fresnel interferential schemes.

If the eye-piece O is placed in such a position as to disclose the reflection of slit S without recourse to the lens L, or, in other words, if the rays beamed from points S_3 and lying in an axial plane of the cylindrical lens L will form an image in the object plane of the eye-piece O, then the interferential pattern observed through the eye-piece will at every one of its cross-sections by the plane perpendicular to the images S_1 and S_2 be determined by the distance of points S_3 from a certain fixed plane.

If the surface T is not flat, the shift of interferential bands will be proportional to the aforementioned distance. In other words, the interferential bands will be wavy, and their form will reproduce the profile of the plane under observation at a cross-section corresponding to the position of the image.

The width of the band is inversely proportional to the distance between the images S_1 and S_2; this distance in turn depends on that between the rays falling on mirror P_1 and reflected by mirror P_2. The narrowest dividing line between the mirrors is thus essential.

In the diagram above, the mirrors P_1 and P_2 were replaced by the prism of full internal reflection, in which the cathetus planes served as the mirrors P_1 and P_2. This disclosed considerable influence of elliptical polarization in the case of full internal reflection from the surfaces of P_1 and P_2. Yet coating one of these surfaces with aluminium will nearly eliminate this effect, which tells so drastically upon the contrast of the interferential bands.

When placing the prism in the path of the beam from O_2, it is necessary to place a glass of equal thickness in the path of the beams from O_1.

Objectives $8\times$ with 0.20 aperture were used in the diagram above, and the insertion of a 3 to 5 mm glass slide did little to change the quality of the reflected images.

Tests of the apparatus designed on the aforementioned principle fully demonstrated its feasibility for the study of micro-profiles. The interferential pattern will convey a clear idea of the minutest irregulatities in the surface under observation and will facilitate estimation of the correct degree of deviation. When other than flat surfaces are observed, that of spheres or cylinders, for example, the apparatus will depict the curvature of the surface at a given cross-section. Smoothly curved interferential bands will reveal delicate deviations corresponding to the microscopic traces of tooling or wear. The picture will be clear, and deciphering will therefore offer no difficulties.

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CHEMISTRY

ON THE INFLUENCE OF OXIDATION PROCESSES ON THE FLOTABILITY OF SULPHIDE MINERALS

By I. N. PLAKSIN

(Communicated by A. A. Skochinsky, Member of the Academy, 1.XI.1944)

It has been shown by a number of investigators ([1], [2]), that during flotation the surface of sulphide minerals is rather highly susceptible to oxidation. At the same time the aqueous extract is found to contain a negligible quantity of soluble sulphates, and hence it may be assumed that the oxidation products are fixed on the surface of the mineral.

When the surface is treated with xanthate, considerable quantities of sulphate ions pass into solution, which shows that fixation is chemical in nature.

It is also known that appreciable oxidation of sulphide ores (in the deposit itself, during mining, after mining while lying on the surface, *etc.*) leads to a lowering in flotability, the magnitude of the effect depending upon the mineral.

The latter circumstance points to the possibility of selective separation of sulphide minerals by treatment with oxygen. This is confirmed by the practice of pulp aeration at a number of American plants for the flotation of ores with a considerable iron sulphide content. Thus, the introduction of pyrite and pyrrhotite cycles in the flotation flowsheet, and pulp aeration at the Noranda plant in Canada, which dresses pyrite copper-gold ores (with a total sulphide content of 80 per cent) containing 6.8 per cent chalcopyrite, 22.1 per cent pyrite, 51.3 per cent pyrrhotite and 4 g/ton gold, resulted in a rise in the recovery of gold from 65.68 to 79.13 per cent, and of copper from 92.77 to 96.9 per cent ([3]).

Aeration was also employed with good results at the United-Verde copper-pyrite flotation plant, at the Utah-Consolidated flotation plant and at the Stirling copper-lead-zinc-pyrite flotation plant ([4]).

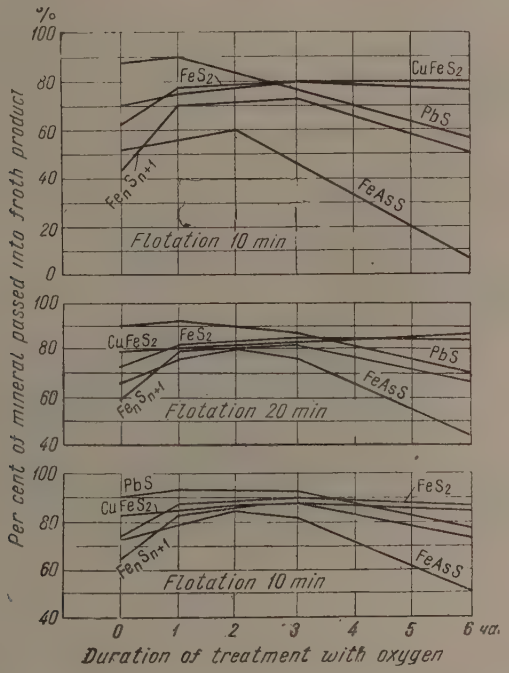
Heretofore, however, there has been no mention of the use of pure oxygen in selective flotation.

Laboratory experiments carried out by the author in collaboration with A. I. Sinelnikova and A. S. Yelisseyeva showed that pure oxygen is much more effective, and, moreover, indicated that the oxygen dissolved in the liquid phase of the pulp affected the flotation activity of minerals differently, depending upon the ratio of the number of metal atoms to the number of sulphur atoms in their molecules (see figure).

Thus, in the flotation of chalcopyrite ($CuFeS_2$) and pyrite (FeS_2) the amount of the mineral that passes over into the froth concentrate increases during the first three hours (particularly during the first hour) of preliminary saturation of the pulp with oxygen, and does not decrease even when the saturation is continued for 6 hours. In the flotation of galena (PbS), on the other hand, a sharp decrease in flotability sets in after the first hour of preliminary saturation with oxygen.

A similar decrease in flotability after preliminary saturation of the puld with oxygen is observed in the case of arsenopyrite (FeAsS), sphalerite (ZnS), pyrrhotite (Fe_7S_8) and chalcocite (Cu_2S); auripigment (As_2S_3) and antimonite (Sb_2S_3) behave in a similar manner.

Thus, minerals whose molecules contain two sulphur atoms do not exhibit a decrease in flotability in neutral or acid solution even after prolonged oxidation (for a period of 6 hours) by bubbling oxygen through the pulp. In the case of minerals whose molecules contain one sulphur atom, on the other hand, flotability decreases either immediately after saturation with oxygen is begun or after one hour.



For minerals whose molecules contain less than two sulphur atoms, the dependence of the flotability upon the oxidation is like that for minerals whose molecules contain one sulphur atom.

When flotation is protracted (30 min. in a laboratory machine) differences in flotability of minerals are evened out somewhat.

Thus, selectivity maximum after saturation of the pulp with oxygen may be achieved by increasing the velocity of flotation (see figure).

To characterize the degree of oxidation of the mineral surface by oxygen, it is well to draw a parallel with the experiments on the influence of preliminary treatment with hydrogen peroxide upon the flotability, as observed by this and other authors. Owing to the fact that the slightly stable hydrogen peroxide molecule decomposes rather readily, a considerable amount of atomic oxygen is liberated, which leads to excessive oxidation of the surface of all the minerals and to a decrease in flotability due to the formation of an oxide film.

Employing oxygen dissolved in water one may achieve much more selective oxidation without affecting the flotability of minerals with a larger sulphur content (pH $\leqslant$ 7).

Mention needs to be made of the fact that hydrogen peroxide enhances the flotability of antimonite and realgar. It also lowers flotability of chalcopyrite to a smaller degree than that of other minerals.

To elucidate the part played by the soluble oxidation products one should compare the flotation of minerals after separating them from the solution with flotation of minerals with fresh faces mixed with a solution containing oxidation products (after bubbling oxygen through).

A study of this problem reveals that though the soluble oxidation products of the minerals affect flotability in most cases, still they do not determine the influence of oxidation on flotation.

A study of the processes taking place during the oxidation of the surface layer of a mineral reveals considerably more complex phenomena than predicted in a schematic treatment of the formation of sulphide-sulphates ([2]).

It is necessary to take into account that in a given case not individual molecules but the total surface of the crystalline substance is acted upon.

In conformance with the recent paper by Gaudin and Vincent ([5]), based upon the introduction in the solution of radioactive ions, one should also take into account the ability of individual elements to diffuse in the surface layer, which may lead to the formation of new structures in the surface layer of the minerals. Moreover, the nature of the bond in the crystalline lattice affects the conditions of the formation of surface compounds during the oxidation of a mineral.

Oxidation with oxygen may prove to be especially effective in the selective flotation of such mineral combinations as chalcopyrite and galena, pyrite and arsenopyrite, and chalcopyrite and pyrrhotite.

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GEOCHEMISTRY

CHEMICAL FORMULAE OF TOURMALINE, AXINITE AND DUMORTIERITE

By V. I. LEBEDEV

(Communicated by W. I. Vernadsky, Member of the Academy, 15.VIII.1944)

During a study of the tourmalines of Northern Karelia it was found impossible to calculate some of the chemical analyses of this mineral satisfactorily according to the usual Kunitz' formulae (3). This fact made us undertake a study of the chemical composition of tourmaline in general. The results of this study are presented in brief in this paper.

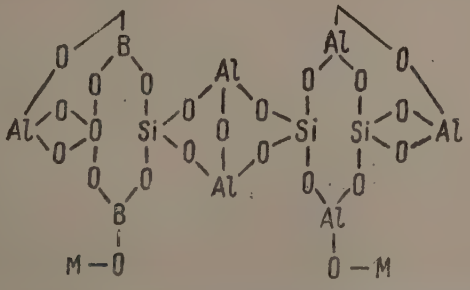
In 1899 Pentild and Foote (4) established that the ratio $B_2O_3 : SiO_2$ in tourmaline was a constant equal to 1 : 4, and indicated that this mineral can be represented as the derivative of a hypothetic acid $H_{20}B_2Si_4O_{21}$. But since tourmaline always contains aluminium, and that part of the hydrogen, which the authors considered to be in combination with boron, can never be substituted by metals, they wrote the general formula for tourmalines as follows: $H_9Al_3(B, OH)_2 . Si_4O_{19}$.

In 1913 Schaller (5) confirmed Pentild and Foote's conclusions and showed that Al_2O_3 in tourmaline is in inverse proportion to the sum $MgO + FeO + MnO + CaO + Na_2O + Li_2O + K_2O + H_2O$ (residual) $= RO$. On the basis of this fact the author concluded that tourmaline cannot be represented by one formula, and suggested a series of formulae: 1) $12SiO_2 . 3B_2O_3 . 9Al_2O_3 . 3H_2O$; 2) $12SiO_2 . 3B_2O_3 . 8Al_2O_3 . 3RO_2 . 3H_2O$; 3) $12SiO_2 . 3B_2O_3 . 7Al_2O_3 . 6RO . 3H_2O$, *etc.*

In 1914 Vernadsky (6) found in Schaller's data confirmation of his assumption that tourmaline consists of two nuclei, with an addition group, which were expressed by him as far back as 1912 in the following general formula

$$(P.M_2B_2Si_2O_2 . M_2Al_2Si_2O_2) . 2A.$$

The structural pattern of this formula, for example, for a tourmaline rich in aluminium (called elbaite) was as follows:



More recent papers on the chemical structure of tourmaline did not bring anything new in principle, and Kunitz' paper (3) which introduced into this

formula a constant quantity of Na_2O and a larger quantity of H_2O, was far from helping to solve the problem.

Kunitz [3] proposed the following series of component formulae for tourmaline:

Schorl — $H_8Na_2Fe_6Al_{12}Si_{12}B_6O_{63}$
Dravite — $H_8Na_2Mg_6Al_{12}Si_{12}B_6O_{63}$
Tsilosite — $H_8Na_2Mn_6Al_{12}Si_{12}B_6O_{63}$
Uvite — $H_8Ca_2Mg_8Al_{10}Si_{12}B_6O_{63}$
Rubellite — $H_8Na_2(Li,Al)_3Al_{12}Si_{12}B_6O_{63}$
. . . . — $H_8Na_2(Mg,Fe)_5Al_{14}Si_{12}B_6O_{63}$

In order to prove that it is quite impossible to calculate some chemical analyses of tourmaline according to these formulae, I refer the reader, for example, to analysis No. 10 given in Levenfish's paper [2]. After calculating this analysis for uvite by CaO and for rubellite in Li_2O we get a remainder of 26.2 per cent SiO_2, 34.1 per cent Al_2O_3, 8 per cent B_2O_3 and 3.4 per cent H_2O, and no bivalent metals whatsoever.

The basis for my study was 12 new analyses of tourmaline done by Levenfish: 10 of them were made on Transbaikal tourmalines while developing a new method of analysis for B_2O_3 in tourmalines, and two, on North Karelian tourmalines, were done at my request.

Molecular Ratios in Tourmalines, Analysed by N. V. Levenfish

No.	No. of sample	Colour of tourmaline	Ratios found from by analysis					Ratios calculated according to formula		
			SiO_2	B_2O_3	Al_2O_3	H_2O	MO	Al_2O_3	H_2O	RO
1	2	greenish-black	4	1	1.96	1.39	2.14	2	1	2.5
2	1	black	4	1.02	2.28	1.26	1.91	2	1	3
3	17	»	4	0.96	2.35	1.26	1.68	2	1	3
4	8	»	4	0.97	2.37	1.39	1.59	2	1	3.1
5	6	»	4	0.98	2.42	1.5	1.47	2	1	3.2
6	16	»	4	0.99	2.45	1.24	1.5	2	1	3.1
7	5a	»	4	0.96	2.52	1.35	1.46	2	1	3.3
8	22	green	4	0.98	2.46	1.39	0.96	2	1	3.2
9	7	»	4	1.03	2.5	1.58	1.12	2	1	3.1
10	5	»	4	0.96	2.51	1.53	1.08	2	1	3.1
11	21	pink	4	1.02	3.66	2.07	0.44	2	1	3.5
12	10	»	4	1.04	2.71	1.62	0.49	2	1	3.2

Remarks. Analyses No.1 and No. 2 are from Northern Karelia; No. 1, from the Kerety Island, quartz-carbonate vein; No. 2, from the Krivoe Lake, pegmatite vein. All the rest of the analyses are from the Transbaikal; No. 3 and 6 are from the Kamennaya Strelka deposit; No. 11, from the Mokhovaya deposit; Nos. 4, 5, 7, 8, 9, 10, and 12, from the Usovaya deposit.

A study of this material, given in the table and also of a large number of old analyses and several new ones of tourmaline (particularly, those of Kunitz [3], Schaller [5] and others, *e. g.* from Delter's summary) besides confirming the conclusions drawn in papers [4] and [5] that the $H_2O : B_2O_3 : SiO_2$ ratio in tourmalines equals 1:1:4 (H_2O may be somewhat higher), resulted in the establishment of two very important rules:

1. The ratio $(Al_2O_3 + Fe_2O_3) : SiO_2$ varies but never falls below 1 : 2.

2. If the quantities of MgO, FeO, MnO, CaO, Na_2O, Li_2O, K_2O which are present in tourmaline in varying amounts (from 0 to several per cent) are added to the excess of Al_2O_3 * and H_2O above the quantities needed to make up their

* In calculating the Al_2O_3 excess is multiplied by 3 to make it equivalent to the oxides of bivalent metals.

proportion to SiO_2 as equal to 1 : 1 : 4, ratio of the resulting sum to $SiO_2/4$ is ciose to 3, deviating in either direction from 2.2 to 3.6.

These rules make it possible to represent the formula of tourmaline as follows:

$$4SiO_2 \cdot B_2O_3 \cdot 2Al_2O_3 \cdot H_2O \cdot 2.2-3.6RO$$

or

$$H_2B_2Al_4Si_4O_{18} \cdot 2.2-3.6\,RO$$

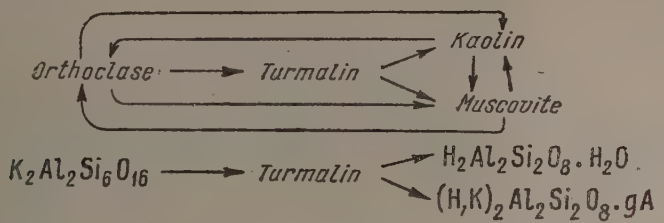
$H_2B_2Al_4Si_4O_{18}$ is the base of any tourmaline, while 3RO in various tourmalines is represented predominantly sometimes by MgO and FeO, sometimes by Al_2O_3. Of the other oxides only MnO may have a considerable magnitude equaling up to 1 RO out of the 3RO.

CaO, Na_2O, Li_2O, *etc.* taken separately never rise above $^1/_3$ RO of the 3RO.

In the first case we get the ferro-magnesia or the schorl-dravite series of tourmalines (schorls, dravites, uvites, indigolites, *etc.*), while in the second we get the aluminium or elbaite series (elbaites, rubellites, polychrome tourmalines, tsilosites (?) *etc.*).

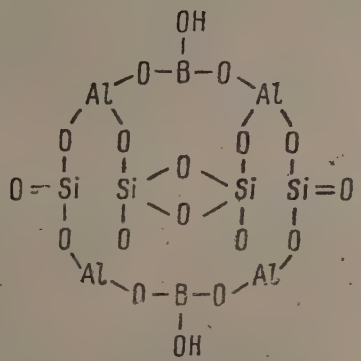
Hence, analytical data show the presence of a definite oxy-boro-alumosilicate complex or nucleus in tourmalines.

Let us now turn to some chemical reactions, sometimes observed to take place in the Earth's crust, which result in the formation and destruction of tourmaline. These reactions can be very well expressed by the following diagram given by Vernadsky (⁸):



This diagram of the processes of formation and destruction of tourmaline shows the predominance of the so-called kaolin nucleus, which Vernadsky considers to be the basis of feldspars, muscovite and kaolin.

Hence it follows that the kaolin nucleus should be the basis of tourmaline as well. This conclusion seems to contradict the conclusion drawn from the analytical material, but this contradiction only appears to exist, and disappears just as soon as we represent the $H_2B_2Al_4Si_4O_{18}$ complex in the form of the following structural formula:



If such a complex really exists in nature, then we have the right to expect:

1. The appearance of this complex in a number of other minerals, differing from one another in their side chains (after Vernadsky).

2. The derivatives of this complex should have a number of common properties.

3. Since it is a very intricate complex, it should be found rarely and form only in processes of a strictly definite nature.

Indeed, at present we can name two more minerals besides tourmaline, in which this complex may easily be detected:

$$\text{axinite} - H_2B_2Al_4Si_4O_{18} \cdot 2Ca_2SiO_4 \cdot 2(Fe, Mn)SiO_3$$

and

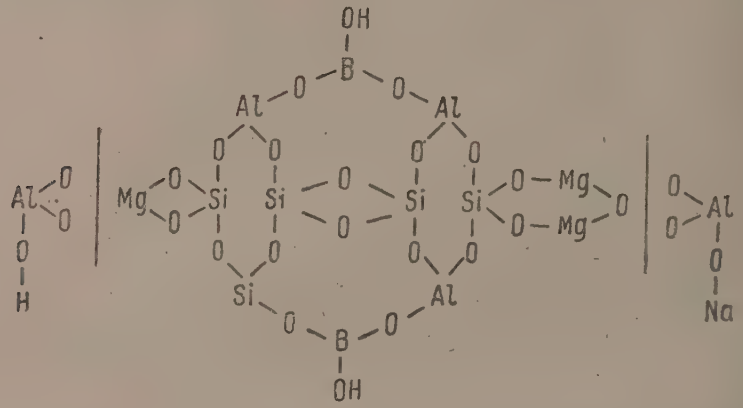
$$\text{dumortierite} - H_2B_2Al_4Si_4O_{18} \cdot 2Al_2SiO_5 \cdot 4Al_2O_3$$

All these minerals, *viz.* tourmaline, axinite and dumortierite, are comparatively rare, and form only when there is no excess of alkalis, in connexion with processes which take place in acid magma and mainly during its post-magma processes.

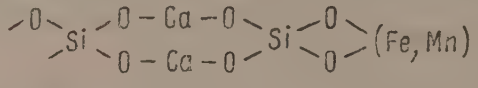
Unlike almost all other silicates and alumosilicates, these minerals are unusually stable at the Earth's surface and are almost inert to acids, including HF*.

Under hydrothermal conditions tourmaline and dumortierite often turn into mica.

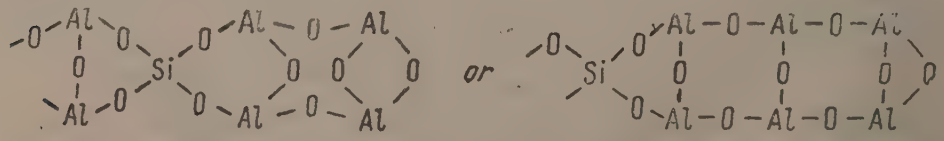
All this makes it possible to express the chemical structure of tourmaline, axinite and dumortierite in accordance with W. I. Vernadsky's views, in the following series of formulae:



The structural formulae of axinite and dumortierite differ only in their side chains. For instance, axinite will have the following group in its side chains:



and dumortierite will have



It must be noted that the individual features of each variety among these minerals, particularly in tourmaline and axinite, may easily be expressed by the

* HF acts on axinite, but very weakly. This is probably due to the presence of ortho- and metasilicates in the side chain of axinite.

ratio of oxides in the side chain, *i. e.* by the RO group. In tourmaline this would mean the ratio Al_2O_3 : FeO : MgO : CaO and the alkalis; in axinite, CaO : FeO : : MnO. A number of properties such as colour, specific gravity and optical data, depend upon these ratios. For instance, the refraction index especially increases as the FeO content rises.

From the standpoint given here on the chemical structure of tourmaline, axinite and dumortierite, the geochemical fate of boron becomes especially clear. Under the normal conditions of late- and post-magmatic processes in acid magma tourmaline forms; if the medium is low in Mg and Fe content, aluminous tourmaline is formed, but if their content is high, the ferro-magnesia variety occurs. In such cases, where calcium plays an important part, *e. g.* at contacts, axinite is generally formed. In those cases, where, on the contrary, aluminium predominates over the alkaline earths, and the silica content is low, dumortierite is formed. In the course of secondary processes the oxy-boro-alumosilicate-tourmaline complex becomes unstable. This results in its weathering away to the simpler components of the kaolin nucleus, and boron disappears to form borates later on. Under such conditions when the tourmaline complex does not form at all, boron crystallizes out comparatively late and forms boro-silicates (danburite, datolite) or numerous borates.

In concluding it must be noted that the solution of the problem of the chemical formula of tourmaline, axinite and dumortierite proposed in this paper offers further confirmation of the kaolin nucleus theory.

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GEOCHEMISTRY

ISOTOPIC COMPOSITION OF THE WATERS OF UPPER SVANETIAN GLACIERS

By R. V. TEIS and K. P. FLORENSKY

(Communicated by A. E. Fersman, Member of the Academy, 24.III.1945)

The problem of the isotopic composition of glacier waters has been discussed in three successive papers, published in 1935. In one of the articles G. Mark (1) suggested that glacier ice should be an especially good object for the study of the accumulation of deuterium in natural freeze—melt processes, since upon the territory covered by large glaciers the same ice block freezes and melts a great number of times in the course of a considerable number of years. In order to observe this phenomenon 50—60 samples of Alpian glacier waters were taken. Among these samples some had an increased, and others a decreased content of deuterium (the $H_2O : D_2O$ ratio varied from 3000 : 1 to 10000 : 1). However, this article gives no definite figures, nor does it describe the method of purification and measurement.

The other two papers, which are to some extent connected with the first mentioned, are about the isotopic composition of glacier waters of the Swiss Alps (Bern Oberland) (2) and of the Caucasus Mountains (3). Both of these papers also show that some glacier water samples have an increased, while others have a decreased content of deuterium, but both papers base their conclusions only on density measurements. Besides, in paper (3) the densities are taken, as the authors themselves indicate in one of their subsequent papers, in relation to water differing in its isotopic composition from the universally accepted standard—river water.

Paper (5) gives a full isotopic analysis of the rivers of mountainous Karachai, which are of glacier origin. Some of these waters, in spite of dilution with spring waters, still retained an isotopic composition near to that of snow: in no case was accumulation of deuterium observed; on the contrary, its content was always lower than in river water. But the heavy oxygen content was higher than in river water.

We took sample of ice and ice water from the glaciers of Upper Svanetia, and samples of the waters of the Ingur River all along that part of the river which flows through Upper Svanetia. The samples were taken in July and August, 1939.

The samples were purified after the method proposed by Emeleus (6) and the measurements were made after the method of combined density and refraction index determination, the error of our measurements being: for the resultant density ± 0.2; for the refraction index $\pm 0.5 \cdot 10^{-7}$, while separate determination gives an error of—1.0. The following data were found.

Sample, No.	Place of sampling and description of sample	Density increment		
		Δd_s	Δd_D	ΔdO^{18}
1	Water from the Adishi Glacier (stream water from the surface of the glacier)	+5.8	—5.8	+11.6
2	Ice from the Adishi Glacier	+3.6	+3.5	0
3	Ice from the Yukhvan Glacier	—0.5	—3.9	+3.4
4	Water from the Gul Glacier	+1.6	—3.0	+4.6
5	Water from the Ingur River (near the village of Ushguli)	+3.4	—6.2	+9.6
6	Do (near the village of Latali)	—1.2	—1.3	0
7	Do (near the village of Khaishi)	—1.2	—1.3	0

Thus, only one sample of glacier ice proved to have a somewhat increased content of deuterium. All the rest are of the same type, as far as their isotopic composition is concerned: their deuterium content is lower than in river water, while the heavy oxygen content in most of the samples is either somewhat higher or equal to its concentration in river water.

The samples of Ingur River water were taken all along that part of it which flows through Upper Svanetia, at approximately equal intervals. The sample taken close to the source of the river (at the village of Ushguli) has an isotopic composition close to that of glacier ice water; farther down the river the nature of the isotopic composition remains the same, but, evidently, due to dilution with waters of another nature the deuterium content increases, and the O^{18} content returns to normal.

The composition of the samples taken near the villages of Latali and Khaishi, in spite of the considerable distance between these two points (about 40 km), was identical.

Conclusions. 1. In all the samples of glacier water but one the deuterium content was found to be lower than in river water; the heavy oxygen content is normal or somewhat high.

2. The waters of that part of River Ingur which flows through Upper Svanetia has an isotopic composition similar to that to glacier waters, with the exception of one sample which was taken near the source of the river and which was found to contain less deuterium and more O^{18} than the samples taken lower down the river.

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GEOCHEMISTRY

ON THE QUESTIONS RELATED TO THE ORIGIN OF INDER BORATES

By J. J. YARZHEMSKY

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The Inder geological-prospecting group of the State Institute for the studies of mineral and chemical raw materials has recently been carrying on petrographical-mineralogical, geochemical and hydrogeological investigations at «Inderborstroy», Guriev region, with the aim to shed light upon the origin of Inder borates. This paper contains the conclusions derived from petrographical-mineralogical materials, with the purpose to trace the principal lines in the scientific and practical investigations of boron occurrences that are intimately associated with the rich potassium deposits of the Inder salt-dome uplift.

1. The works carried out have firmly established the fact of an extensive development of kaliborite occurrences in the potassium salts of the uplift, and the transitions of kaliborites to ascharites in the zone of leaching off salts. When a metasomatosis of kaliborite by ascharite takes place, there are observed either micro-aggregate structures of the latter, or the appearance of isolated micro-acicular structures of ascharite, their tufts or needles piled up at random, which made us separate a structure termed the «pile of needles» structure.

2. A scheme of the ways of migration and boron metasomatosis has been proposed:

The first zone—boron-bearing potassium deposits of the Inder salt-dome uplift. Here primary borates are present (mainly, kaliborites) in the form of independent accumulations or in different parageneses mainly with kainite, sylvite, polyhalite and carnallite minerals. Higher up one may observe the behaviour of boron occurrences under conditions of hypergene processes.

The second zone (of leaching off salts) is characterized by the appearance of ascharite. Different parageneses of ascharite and still preserved kaliborite occurrences with sylvite, polyhalite, carnallite and kainite components in the zones of leaching off salts.

The third zone—over the salt table (the principal aquifer of the gypsum cap). There is an almost complete metasomatosis of kaliborite, mainly by ascharite. Chiefly ascharite is retained, frequently forming gypsum-ascharite veins over the boron-bearing potassium deposits. Part of the boron is removed by solutions.

The fourth zone—the gypsum cap from the level of the basal aquifer to the day surface. Complicated ways of metasomatosis of a part of ascharite bodies, bringing about the formation of inyoite, colemanite, pandermite, ulexite and hydroboracite mineralizations. The migration of boron in the rocks of the caprock

and their partial fixation in the shape of non-ascharite components, associated mainly with pelitic rocks.

3. From the author's observations, the borate metasomatosis in ascharite deposits proceeds in an intimate association with processes of carbonatization of gypsolite formations of the caprock in general, and with carbonatization of ascharite ore bodies in particular. Examples of calcitization of the gypsolites of the caprock, mainly near the day surface, are frequent.

The phenomena of boron metasomatosis are not infrequently accompanied at the contacts of the nearly formed carbonate bodies and ascharite ore bodies by the formation of magnesial silicates—sepiolite, which is precipitated together with a part of the excessive amount of silica as opal. It has been established that the sepiolite formed changes its properties rather soon and from «soapstone» is converted into lithified rocks which approach carbonates in their hardness.

The sequence of formation of borates of the non-ascharite series must depend on the geochemical surroundings in which proceed the reactions of boron metasomatosis. In most cases, the boric acid produced from ascharite as a result of natural reactions, interacts with the gypsum solutions, which accounts for the frequent appearance of calcium borate newly formed minerals of the inyoite-colemanite-pandermite series in the ascharite ore bodies. The least known are the ways of formation of ulexite and hydroboracite ores.

The behaviour of fluorine compounds in the processes of boron metasomatosis of ascharite rocks is of interest. Earlier investigations of Egorova [1] have shown that the highest content of fluorine compounds is observed in ascharite ores; non-ascharite ores are poor in it. In the author's opinion this is due to the fact that as a result of a posthumous boron metasomatosis a removal of fluorine compounds takes place at those places where the ascharite ores had been replaced by non-ascharite ones. Over areas of the latter occurs a considerable «refining» from fluorine compounds, an impoverishment in them, while the peripheral carbonated areas are sometimes highly enriched in fluorite. Obviously secondary fluorite nodules were discovered at the places of an intensive boron metasomatosis of the ascharite giant No. 36.

The example of the large borate deposits of the Inder uplift points to the existence of a very distinctly pronounced regularity in the intensive processes of hypergene carbonatization and boron metasomatosis in the upper parts of the ascharite ore bodies, where a number of non-ascharite newly formed bodies come into existence. The lower parts of the borate giants, slightly affected by the agencies causing hypergenesis, retain their almost purely ascharitic composition.

Thus, as shown by the author's observations, closely associated with the processes of carbonatization of gypsolites of the caprock in general and with the carbonatization of ascharite deposits in particular is an intensive boron metasomatosis of ascharite deposits, mainly in the upper portion of the rocks of the gypsum cap. Along with the processes of carbonatization and boron metasomatosis proceeds the formation of secondary magnesium silicates—sepiolite, and a rearrangement of fluorine compounds that were present in ascharites: their removal from non-ascharite newly formed bodies, an enrichment with them of carbonatized areas and peripheral carbonizated zones of ascharite ore bodies, their accumulation in the form of distinctly secondary fluorite nodules in areas of intensive metasomatosis. All this points to a high intensity of secondary processes which take place in the ascharite deposits in the upper part of the zone of hypergenesis.

4. The ascharite deposits belong to residual ones, formed in the zone of hypergenesis by way of a replacement of the kaliborites of the potassium deposits. The author refers all the non-ascharite borate newly formed minerals to residual ones, formed in the process of carbonatization and a posthumous boron metasomatosis of the ascharite occurrences. There are but comparatively scarce, purely non-ascharite deposits of the caprock, chiefly associated with halopelites, that

are possibly migrational (such are, for instance, deposits Nos. 18, 23 and others) or formed during some final stage of the pegnitogene process (the poor but extensive hydroboracite mineralization in red halopelites No. 7), subsequently included in the rocks of the gypsum cap and extending with their «roots» down into the salt beds of the Inder uplift.

5. Under conditions of a pierced shape of the domes of the Inder uplift the rocks of the normal sedimentary complex overlying the salt-bearing beds occupy a peripheral position and have a periclinal attitude on the halogenous rocks. They have quite definite facial peculiarities and with regard to age belong to rocks of the Triassic, Jurassic, Tertiary and Quaternary. Variegated beds and white gypsolites take part in the composition of the peripheral ranges; the white gypsolites are assigned by the author to the Upper Permian.

Within the gypsum cap of the proper Inder uplift in some rare instances occur primary-sedimentary deposits, which had previously either taken part in the composition of the beds overlying the salt-bearing strata, or represented intraformational boron occurrences within the salt series. They are also referred by the author to the Upper Permian, although the possibility is not quite excluded that they are synchronous with the salt rocks (P_1).

During the post-Pliocene time proceeded the shaping of the pierced structure of the domes of the Main Inder uplift and the accumulation of the rocks of the gypsum cap.

Consequently, all the other halogenous products that had been subject to the action of agencies of hypergenesis are considered as secondary rocks of a post-Pliocene age. They are represented chiefly by gypsolites of the most diverse shades of grey (dark-grey, grey, light-grey, spotted, banded). They should be referred only to separate lithological varieties, without raising them to the rank of independent stratigraphical horizons.

Name of borates	Chemical composition	Refractive index			$N_g - N_p$	Spec. gravity
		N_p	N_m	N_g		
Kaliborite	$K_2O.4MgO.11B_2O_3.18H_2O$	1.508	1.526	1.550	0.042	2.13
Ascharite	$2MgO.B_2O_3.H_2O$	1.577	1.642	1.646	0.069	2.69
Inyoite	$2CaO.3B_2O_3(13.8)H_2O$	1.494	1.505	1.520	0.026	1.87
Colemanite . . .	$2CaO.3B_2O_3(5.3)H_2O$	1.586	1.592	1.614	0.028	2.42
Pandermite . . .	$5CaO.6B_2O_3.9H_2O$	1.574	1.585	1.593	0.019	2.40
Ulexite	$2CaO.Na_2O.5B_2O_3.16H_2O$	1.491	1.504	1.520	0.029	1.65
Hydroboracite . .	$CaO.MgO.3B_2O_3.6H_2O$	1.523	1.524	1.570	0.047	2.167
Hilgardite	$6CaO.2CaCl_2.9B_2O_3.4H_2O$	1.636	1.636	1.664	0.028	2.71
Boracite	$5MgO.7B_2O_3.MgCl_2$	1.662	1.667	1.673	0.011	2.95

Among the carbonates of the caprock undoubtedly secondary rocks (chiefly limestones and dolomitic limestones) of the post-Pliocene are established, part of which are a product of carbonatization of the ascharite ore bodies.

As shown above, the ascharites of the borate deposits are residual products of a metasomatosis of the kaliborites of potassium salts (sylvite, polyhalite, kainite).

The ascharites should be regarded as syngenetic with the grey gypsolites enclosing them, since these gypsolites are also a residual insoluble material of the halurgy complex. This, in the author's opinion, points to a post-Pliocene age of the ascharite mineralizations of the gypsum cap of the Inder uplift, while the formation of the parent magnesium borates is synchronous with the process of sedimentation of the potassium salts of the Lower Permian. Hence, only accumulations of non-ascharite borate newly formed bodies of the ascharite ore deposits are epigenetic with respect to the gypsolite of the caprock enclosing the ore bodies, belonging largely to the latest stage of the post-Pliocene. The ascharite ores and the grey gypsolites enclosing them are considered by the author as syngenetic post-Pliocene formations.

6. Together with the previous investigators of Inder (with A. N. Volkov in particular), a prognosis has been formulated concerning the territorial co-occurrence of ascharitic borate deposits of the caprock and of potassium deposits within the salt-dome uplift.

7. The idea of a complex utilization of potassium salts and borates occurring at large depths, previously advanced by A. N. Volkov, has been fully confirmed by all the investigations carried out during the last three years by the Inder geological-prospecting group of the State Institute of Mining and Chemical Raw Materials. The potassium-boron problem occupies an important place in the immediate working program of the large chemical combinate of the Big Inder.

In the table are given the principal properties of the chief borates of Inder.

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BIOCHEMISTRY

ON THE REDUCTION OF ORTHO-DINITROBENZENE IN GREEN PLANTS

ON THE MECHANISM OF PHOTOSYNTHESIS

By A. A. GUREWITSCH

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In our previous note (1) it has been shown how by changing air supply and illumination conditions it is possible to demonstrate that the reduction of ortho-dinitrobenzene and ortho-nitrophenylhydroxylamine to ortho-nitraniline is realized in the green plant by way of two independent processes: under a somewhat limited supply of oxygen it accompanies respiration in all cells, whereas under liberal aeration it proceeds in such green cells only as are exposed to light.

These observations made us conclude that the reduction of ortho-dinitrobenzene to ortho-nitrophenylhydroxylamine in exposed green parts of the plant is a result of the photochemical effect of light, produced under participation of green plastids.

A discussion of the results of our experiments, their comparison with literary data on the reduction of nitrates in the green plants, and especially an analysis of the well-known study by Warburg and Negelein (2) made it seem highly probable that, like the reduction of nitrates, the reduction of ortho-dinitrobenzene and ortho-nitrophenylhydroxylamine in green cells exposed to light is directly associated with the primary photochemical process which takes place in green plastids, and proceeds independently of the assimilation of carbon dioxide.

The last conclusion being essentially important, its direct verification made in an experimental way appeared to us desirable.

The present note is an account of our attempts to shed light upon the problem referred to above with the aid of experiments, where the reduction of ortho-dinitrobenzene in green leaves exposed to light would take place in a medium freed from carbon dioxide. As a material for these experiments use was made of young leaves of wheat, severed from the plant; the experiments were so arranged as to permit of a maximum air supply to the leaf-summits immersed in the solution, under which no reduction of ortho-dinitrobenzene takes place in the dark.

The only difference between our new experiments and those described in our previous note (1) consisted in that into the test-tube containing the leaves, which was tightly stopped with a rubber stopper sealed with paraffin, we introduced a tightly rolled strip of filtering paper soaked in a 30 per cent solution of caustic potash or sodium, in order to absorb the carbon dioxide formed; this strip of filtering paper was placed under the stopper so as to avoid any contact either with the leaves, or with the dinitrobenzene solution. The light was supplied from an electric bulb of 100 watts, placed at a distance of 15 cm from the test-object. The experiments were run at a room temperature of 16—17°C, and continued during 24 hours; their results were compared with those of experiments carried out without elimination of carbon dioxide. As controls served experiments with leaves of wheat, carried out in the dark.

Our experiments went to demonstrate that the reduction of ortho-dinitrobenzene by wheat leaves exposed to light proceeds in a medium deprived of carbon dioxide at the same rate as in a medium from which carbon dioxide has not been eliminated. In either case the solution assumed an intense yellow colour, and showed an equally strong diazo-reaction for ortho-nitraniline; the ammonia-reaction for ortho-nitrophenylhydroxylamine was negative in both cases. As should be anticipated, ortho-dinitrobenzene failed to be reduced in the dark in our control experiments. The experiment was run in tenfold replication, and identical results were invariably obtained.

It is necessary to quote here a remark made by Prianishnikov ([4]) who analysed Godlewski's experiment ([3]), in which this writer also eliminated carbon dioxide, in order to make out whether the reduction of nitrate in green plants is affected by light directly or indirectly, through the assimilation of carbon dioxide. Prianishnikov is right in pointing out that «the writer (Godlewski) believed in this way to prevent assimilation, but the carbon dioxide expired by the plants seemed to be partly assimilated by them before it reached caustic potash». It is beyond any doubt that under the experimental conditions here described, carbon dioxide is not fully eliminated; its intensity is considerably decreased, however, for the plant is now allowed to dispose but of a definite portion of the respiration carbon dioxide.

On account of the fact that in our experiments this circumstance did not tell upon the reduction of ortho-dinitrobenzene, we feel authorized to consider their results as a proof of that the reduction of ortho-dinitrobenzene in green cells exposed to light proceeds independently of the assimilation of carbon dioxide.

We thus are brought to a confirmation of what has been assumed in our previous note ([1]), *viz.* that the chloroplasts are not merely organs of carbon dioxide assimilation: they also serve as centres of other reduction processes in the vegetable cell, which proceed under direct participation of light energy. In particular, this is true of the reduction of nitrates in green plants exposed to light.

It is well-known that recent studies carried out on most diverse biological material under application of radioactive isotopes of carbon have shown that any live cell seems to be able to reduce carbon dioxide in the dark, in the same way as it is able to reduce nitrates and ortho-dinitrobenzene ([5],[6]). The two processes should be regarded as analogous to each other, in so far as they use a common source of energy, *viz.* respiration.

From what has been said above it is evident that the similarity of the two processes here described also becomes manifest in green vegetable cells exposed to light, where they seem to be based upon an identical photochemical reaction.

Experiments on the reduction of ortho-dinitrobenzene in green leaves exposed to light permit of definite conclusions with regard to the possible mechanism of this process. These experiments have demonstrated that the reaction of reduction of ortho-dinitrobenzene in chloroplasts exposed to light is chemically identical with that of its reduction in the dark, which proceeds under the participation of hydrogen activized in the process of respiration, whose acceptor is dinitrobenzene. In either case the same intermediate and ultimate products are found to be formed, *viz.* ortho-nitrophenylhydroxylamine and ortho-nitraniline. It seems, therefore, probable that when exposed to light, as well, the reduction of ortho-dinitrobenzene proceeds in green plastids under the influence of hydrogen activized in this case in the course of the photochemical process.

Indeed, during the two last decades the evolution of the theoretical conceptions of the mechanism of photosynthesis has arrived, in spite of some discrepancies in the interpretation of certain important problems, to a conclusion that this process is underlain by the reduction-oxidation reaction which goes on under participation of activized hydrogen due to photochemical splitting (photolysis) of water.

Thunberg ([7]) was the first to point out this «new way from carbon dioxide to formaldehyde». In the subsequent, similar views as to the mechanism of photosynthesis have been advanced by some other writers([8–15]).

From what has been said above it is clear that most of the modern photosynthetic theories are based upon conceptions implying the participation of hydrogen activized in the photochemical process, as the main agent of the reduction of carbon dioxide.

In spite of the fact that such a conception is in full accord with the modern interpretation of the mechanism of redox processes ([16]), it can hardly be considered as proved. According to the fundamental equation of photosynthesis

$$H_2CO_3 \rightarrow CH_2O + O_2$$

the mechanism of this reaction may also be conceived in a different way, as a direct splitting-off molecular oxygen, rather than an addition of activized hydrogen; it is under this angle that it is viewed in the well-known first theory of photosynthesis by Willstätter and Stoll ([17]). According to this theory, in the course of photosynthesis formaldehyde is formed by way of splitting-off a molecule of free oxygen from formaldehyde peroxide, which had arisen during the preceding photochemical reaction from its isomere, the carbon dioxide.

Unlike this, photochemical reduction of ortho-dinitrobenzene in chloroplasts, which leads to the formation of ortho-nitraniline, cannot, as has already been pointed out, take place unless there is direct addition of activized hydrogen to dinitrobenzene, with respect to which the latter acts as an acceptor, as may be seen from the following equation:

$$C_6H_4NO_2 \cdot NO_2 + 2H \rightarrow C_6H_4NO_2 \cdot NH_2 + O_2$$

The assumption that this reaction proceeds by way of addition of a molecule of water, followed by the splitting off oxygen, is lacking sufficient foundation.

Our experiments on the reduction of ortho-dinitrobenzene in green leaves exposed to light may thus be taken to confirm the interpretation of the mechanism of photosynthesis, according to which the latter is brought about under participation of activized hydrogen from a source represented by photochemical splitting (photolysis) off water. The hydrogen of the water, activized in the photochemical reaction, is the main agent operative in other reduction reactions proceeding in the vegetable cells when these are open to the effect of light energy.

Conclusions. Experiments in which the reduction of ortho-dinitrobenzene to ortho-nitraniline in green leaves exposed to light proceeded in a medium freed from carbon dioxide, have shown this photochemical process to take place in the green plants independently of the assimilation of carbon dioxide. Hence:

1) The chloroplasts are not only organs of assimilation of carbon dioxide, but also centres of other reduction processes taking place in a vegetable cell, under direct participation of light energy.

2) The assimilation of carbon dioxide in green plastids, as well as many other reduction processes, that take place in the chloroplasts under the influence of light, is brought about under participation of the hydrogen activized in the course of the photochemical reaction.

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GEOLOGY

ON THE MOST RECENT CASPIAN TERRACES OF THE EASTERN TRANSCAUCASIA

By V. R. VOLOBUEV

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In the Eastern Transcaucasia have been discovered numerous terraces of the Caspian Sea. Geomorphologically, the terraces are distinctly subdivided into high, piedmont ones and low ones, developed in the lowland areas proper, at a level below 0 m *. These two series of terraces differ in their lithological, hydrological, soil and other characters, which make them essentially different from the standpoint of reclamation. Work on reclamation carried out in Azerbaidjan has shown that it is with the low terraces that are associated the most important peculiarities in the ameliorability of the alkaline areas.

All the geological data concordantly point to the young age and the common genesis of the low terraces. They have been formed as a result of changes in the level of the Caspian Sea during its most recent regressive phase which continues up to the present time. To the boundary level of 0 m is confined one of the most distinctly pronounced terraces of the Caspian. This zero terrace is distinctly marked by an abrasion bench passing at a height of 5—0 m, to which usually corresponds a ripple-mark sandy shell-rock barrier. The existence of the zero terrace is moreover well-confirmed by hydrogeological and soil data. Among other evidence it can be distinguished by the nature of the salt composition in the soils and grounds (Fig. 1).

In the submountain regions of the Kura-Arax lowlands the salts are chiefly represented by sulphates with a $Cl : SO_3$ ratio < 0.5. In the area located below the zero terrace, the $Cl : SO_3$ ratio is on the average equal to 1 : 2. The specific character of the salt composition of the area below the zero terrace may be put down to the peculiarities of the salt regime which had prevailed in the Near-Caspian area. After the level of the Caspian Sea did gradually sink as low as 0 m, the slanting piedmont plains became exposed. Upon a further sinking of the level of the Caspian Sea from 0 to —27 m the plain bottom of the Kura Bay began to emerge from under water.

A considerable area freed from water was transformed into marshes because of its low level and plain relief. Along with the formation of marshes, as a result of the mineralized character of the sea waters that remained in the grounds and lagoons, near-shore lagoonal salines became widely developed. Upon a subsequent burial of these saliniferous grounds with fresh alluvium, a vertical shift-

* All the heights are given with reference to absolute zero.

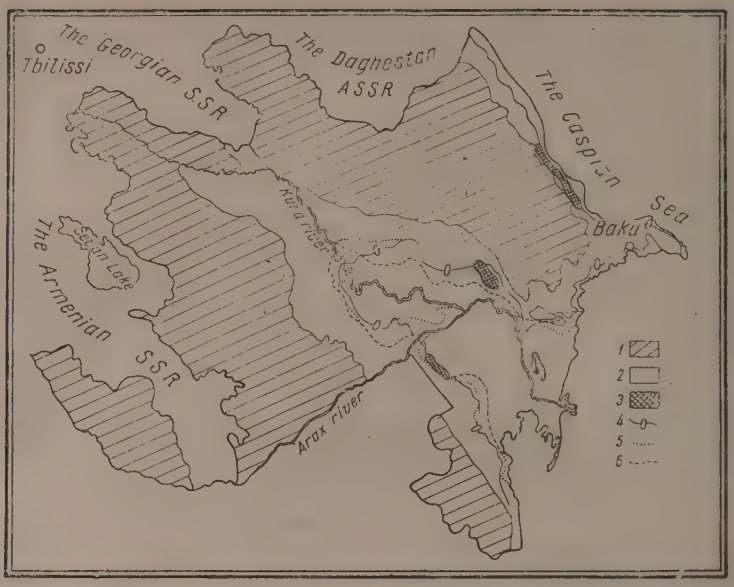

Fig. 1. Map of soil-ground «relicts» of the Caspian Sea in the East Transcaucasia. *1*, Mountain regions of glacial-sculptural tectonic morphogenesis; *2*, plain regions of near-Caspian accumulative-terrace morphogenesis; *3*, areas of fully developed brown semi-arid soils; *4*, zero horizon; *5*, external boundary of the ground waters highest in chlorides; *6*, external boundary of soils with the highest concentration of chloride salts

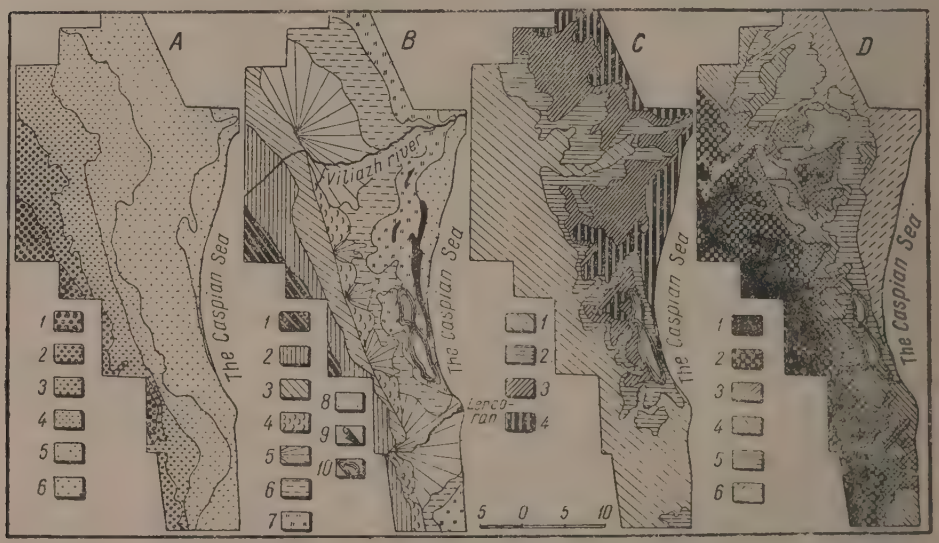

Fig. 2. Maps of the Talysh lowlands, showing the elements of the physical and geographical complex. A. *Hypsometric map* with altitudes: 1) >150 m; 2) 150÷50 m; 3) 50÷0 m; 4) 0÷—15 m.; 5)—15÷—25 m; 6) <—27 m. B. *Geomorphological map. 1*. Eastern slopes of the marginal folds of Talysh; *2*, relict counterforts of the highly eroded 100 m terrace and diluvial gently inclined planes of the 50 m terrace; *3*, slightly undulating diluvial and piedmont alluvial inclined plain with old alluvial fragments of the 0 m terrace; *4*, most recent gently sloping diluvial planes; *5*, most recent piedmont proluvial and alluvial fans of the —15 m terrace; *6*, very gently inclined alluvial and piedmont alluvial train of the — 22 m terrace; *7*, lowland marsh zone of the —25 m terrace; *8*, sandy-silt bench of the —27 m terrace; *9*, sandy shell-rock barriers; *10*, near-shore (marshy) lake, swampiness. C. *Map showing the chloride concentration of the waters*, with reference to the percentage of NaCl to the total amount of salts contained in ground waters: 1) <20 per cent; 2) 20÷40 per cent; 3) 40÷60 per cent; 4)>60 per cent. D. *Map of pH concentration in the upper half-metre layer of soil* (according to salt extract): 1) 4.0÷4.5; 2) 4.5÷ 5,0; 3) 5.0÷5.5; 4) 5.5÷6.0; 5) 5,0÷6.5; 6)>6.5.

ing of salt took place, which necessarily brought about an enrichment of the upper layers of the soil and ground with more mobile chlorides, and an accumulation of sulphates in the lower layers.

The difference in the salt composition of the ground waters above and below the level of 0 m is well pronounced also in the Talysh lowland (Fig. 2,C).

The zero terrace can also be readily distinguished according to the degree of development of soils. In the area below 0 m, as well as in the area of high terraces, in the regions of river alluvial fans and in the submountain diluvial zone, a continuous rejuvenation of the surface takes place. It is only along the mildly slanting diluvial trains of the edge of the zero terrace that the diluvial drift is so slight as not to disturb the course of soil-formation, and the soils formed here are the most mature; in semi-arid regions of the Near-Caspian area there are fallow saline and desalkalized soils (Fig. 1), and in the Talysh lowland, brown post-wood soils.

The ancient age of soils on the zero terrace is also confirmed by the map of pH of the soils of the Talysh lowlands (Fig. 2, D), on which along the line of the bench of the zero terrace passes almost precisely the boundary between the podzolized soils with $pH<6$ and the young leached soils with $pH>6$ (according to salt extract for the 0—50 cm layer).

From a consideration of the elements of the physical-geographical complex, it is possible to distinguish also the post-zero terraces at the levels of —15 m, —22 m, —25 m and —27 m. These terraces are traceable like the zero terrace, after the abrasional benches and ripple-marks, and in saline regions after their salt composition (increase in chlorides in downward direction), and, finally, after the nature of alkalinization. Along with the retreat of the Caspian Sea, proceeded the sinking of the level of the ground waters, as well as the sinking of the salts. On the zero terrace the salts are entirely leached out from the upper horizons to the lower ones, to a depth up to 1—1.5 m.

The alkalinization process developed in the past has almost entirely stopped now owing to the carbonate nature of the soils, but the soils are apt to rapid alkalinization. In the soils of the —15 m terrace the salts have been also leached but only to a depth of 20—40 cm, and in the leached horizons the alkalinization process is distinctly pronounced. The terrace at the level of from —15 to —22 m shows a highly variable salt concentration, either solonetz, or saline one. The terraces below or above —15 m differ considerably as to their lithological structure. The terrace of the —15 m level is composed of lighter alluvium, generally of a loamy mechanical composition. The terrace of the —22 m level has mainly a clayey mechanical composition. Very peculiar is the terrace of the level from —22 to —25 m. In arid regions with a low water content to this terrace are confined salines. In the regions with abundant precipitation or with a considerable and hampered surface drainage of water this terrace is boggy and is of a typical marshy character with sandy shell-rock barriers and with marshy lakes before them (Fig. 2, B). The —27 m terrace has been formed within the recent years only and presents a recent silty beach.

Thus, the use of the geomorphological, lithological, hydrogeological and soil data is of great interest in settling palaeogeographical questions in the East Near-Caspian area.

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HISTOLOGY

INFLUENCE OF CALCIUM CHLORIDE UPON THE COURSE OF HISTOGENETIC PROCESSES IN *ANURA*

By N. E. VASSILIEVA

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The present investigation is a fragment of a series of studies devoted to the problem of the influence of chemical agents upon the histogenetic processes during the early embryonic development of vertebrate animals.

Rana temporaria embryos were taken as a material for the present investigation. The roe at the stage of late gastrula or caudal bud was divided into two portions. One of these was transferred to 0.7 per cent calcium chloride solution. The second portion of the embryos were left in pure water and served as control. The experiments were carried on during ten days. The material was fixed with chromium-acetic mixture or chromium-osmium mixture after Fol and embedded into paraffin through chloroform treatment. Sections 6 μ were stained with Heidenhain (1) haematoxylin.

The only difference in the behaviour of the series under comparison during the first two days was the lagging in development of the embryos in the experimental series as compared to the control one. The characteristic microscopic changes began to appear during the third day of development. The great majority of larvae showed the zigzag bending of the tail. The tail itself seemed to be shortened to a significant degree and had the strongly expressed bends in 2—3 points. This change was found to be present in all experimental larvae, its manifestation varying, however, from specimen to specimen. This calcium morphosis, as we call it, became gradually more strongly pronounced, the longer the treatment proceeded.

Different chlorine salts were used in the other series of experiments. Nevertheless, the changes here described were observed in none of them. They should probably be accounted for by the effect of calcium ions.

The microscopic investigation of the material showed that calcium ions, retarding the development of the whole embryo, produced a different effect on tissue differentiation. The differentiation of the ectodermal and endodermal epithelium was inhibited to the strongest degree. It was found to be true for a less degree for the mesodermal (kidney) epithelium. The widening of the kidney tubules without any noticeable increase of their sinuosity was, as a rule, observed in the experimental embryos. Similar processes are characterisitc of degenerating pronephros. However, the lagging behind of the development discards the suggestion as to the beginning of the degeneration processes. The widening of the pronephros tubules and Wolfian duct without any changes in the character of the kidney epithelium was also observed in the case of the influence of Li_2CO_3 upon the axolotl larvae (2).

It was possible to distinguish two periods in the development of the spinal musculature in the experimental embryos. During the first period of development (1—3 days) some inhibition of differentiation of the muscle fibres was observed. This inhibition was manifest in the reduction of yolk resorption and in the development of myofibrilles in the muscle fibres. The second period is probably connected with the beginning functioning of the primitive muscle fibres. At this stage of development was observed the degeneration of the muscle fibres and the shortening of the muscle segment. During the fourth-fifth day of development and later the muscle segments in the experimental larvae were found to be shortened as compared to the control embryos, as well as to the preceding stage of development. On account of this observation one may suppose that $CaCl_2$ at the concentration used causes a prolonged contracture of the muscular fibres with a subsequent disintegration of the fibres. Moreover, an inhibition in the formation of the tail segments was observed, resulting in the shortening of the tail.

$CaCl_2$ did not produce any influence upon the development of the chorda. There was found no difference in the differentiation of the chordal tissue either in the experimental or the control embryos. This autonomy in the development of the chorda, when the development of the other tissues was inhibited to a varying degree, leads ultimately to the tail bending described above. The primary inhibition of myogenesis and the subsequent partial destruction of the muscle segments is responsible for the shortening of the tail in the experimental larvae. The normal rate of development of the chorda must necessarily lead to the formation of a bending, since, as the time of development proceeds, the chorda must be disposed in a gradually shortening casing, formed by the muscles and the epidermis. The chordal bends are very clearly seen on the frontal sections, beginning from the third day of experiment. Occasionally, the angles of these bends press against the body wall. Closely abutting to the epidermis, they cause tensility of the skin to the extent imminent to break through the latter.

The chordal bends were observed not only in the tail but in the body region also. They were not visible from the outside, since the coelomic cavity present here allowed the chorda to bend without causing external deformation of the body itself.

The autonomous development of the chorda similar to that here described was reported out by Svetlov [3] in his experiments on regeneration of axolotl tail, and by Privolnev [4] in experiments on the influence of high temperatures upon developing embryos of the perch. In both cases the rate of the development of the chorda did not coincide with that of differentiation of the other tissues, leading to the formation of anomalies of various types.

Thus, the effect of calcium chlorate solution differs as to the tissues of the developing embryos. Comparing the influence of $CaCl_2$ with that of other salts studied in this laboratory, one may point out some general fatures (lagging in the differentiation of epithelium and non-striated muscles) which are to be referred to non-specific effect. On the other hand, the disturbance in the development of the chordal complex, leading to the formation of calcium morphoses described above, was not observed under the influence of any other salt (KCl, NaCl, LiCl, $MgCl_2$, *etc.*). The effect obtained with calcium chloride should be referred to the specific action of calcium ions upon the histogenetic processes. The results described go to confirm the conclusion of Katznelson [5] as to the possibility of selective influence of chemical agents upon tissue differentiation.

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HISTOLOGY

A CONTRIBUTION TO THE HISTOPHYSIOLOGY OF CAPILLARIES

By G. ROSKIN

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If one compares our knowledge regarding the physiology of capillaries with what is known to us of their finer structure and histophysiological properties, one is forced to acknowledge that we are lagging far behind in our studies of their finer morphology and of their cytophysiology in particular.

Many cytological and histophysiological problems studied in their relation to the various tissues or organs have been scarcely if at all discussed with reference to the capillaries, in spite of the interest the latter offer for the solution of the most important problems of normal and pathological physiology. It is possible that this backwardness may be explained by the particular difficulties hampering the study of the capillary wall and especially of its endothelial cells, one of the most ungrateful objects of histological research.

In our earlier note [1] we reported our findings regarding vitamin C and the isoelectric points of the nucleus and plasm of the cells of capillaries in the various organs of some animals.

The present report deals with the Golgi apparatus and the mitochondria of endothelial cells, as well as with their content in mineral salts and glycogen.—questions that have not been investigated by anybody.

Before we start the description of the results of our observations on the Golgi apparatus (or, as it is more correctly termed at present by many investigators, the Golgi substance), it is necessary to remind that one can consider as established that the Golgi substance is a most important component of the plasmatic system, and particularly so for the cellular processes of assimilation, transformation and excretion of a great number of substances. In this aspect the investigation of the Golgi apparatus of capillary cells is of exceptional interest.

In the endothelial cells of the capillaries of the frog an osmiophilic substance (Golgi substance) is observed, which exists in different cells in a different state. First of all, it should be indicated that the plasm of endothelial cells in general possesses a considerable osmiophilic capacity, which seems to be connected with its high content in the lipoid component. After osmium treatment the plasm of endothelial cells blackens diffusely, and one can see that this blackening is relatively more intense than in the rest of tissues and cells present in the same preparation. We must note that this response to osmium shows a varying intensity in the individual endothelial cells. In many of them one sees that the Golgi substance does remain evenly diffused, but concentrates in certain areas inside of the cells; in most cases in the shape of a clearly visible dark—standing out against a clearer background of the preparation—perinuclear zone (Fig. 1, *z*, *δ*). Particular attention should be paid to cells in which, besides this perinuclear substance, one can see a strongly osmiated layer of superficial plasm (Fig. 1, *a*.

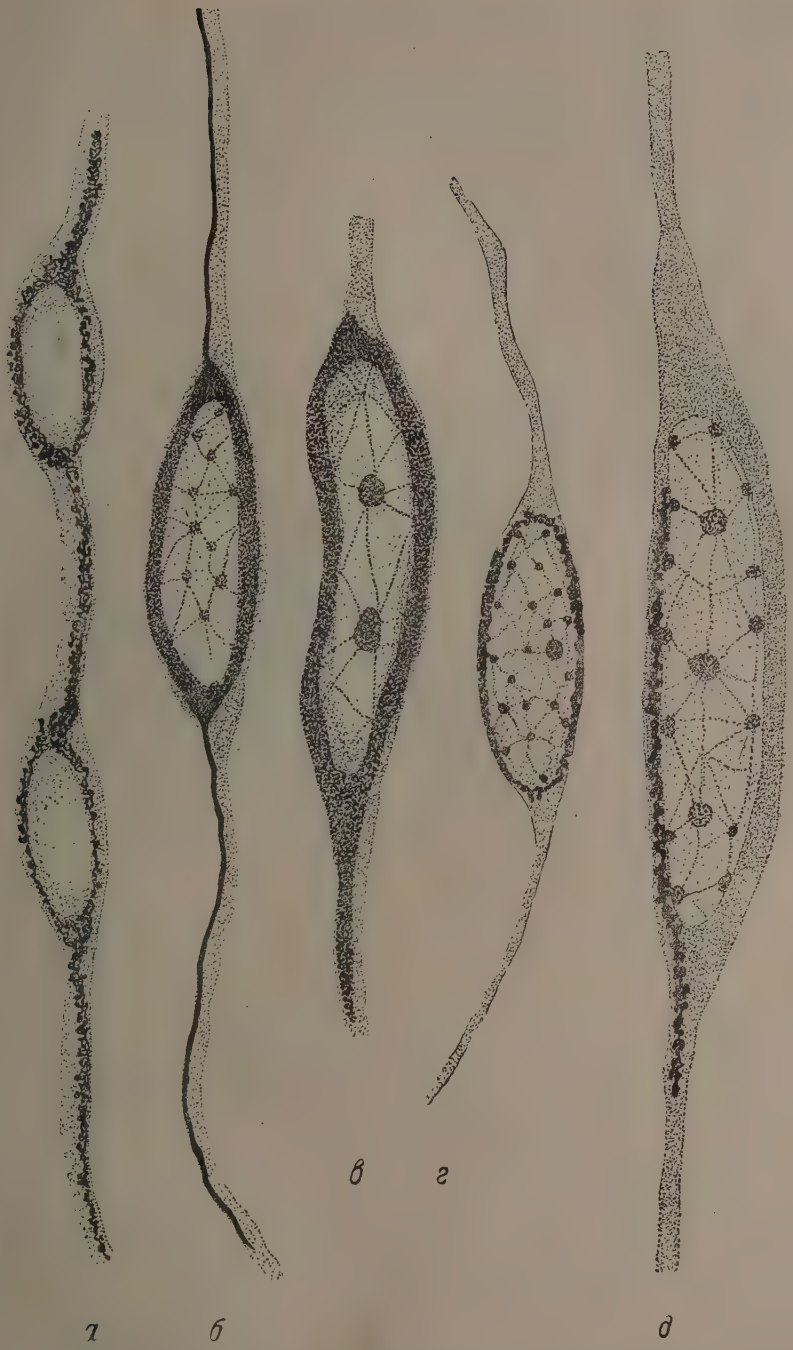

Fig. 1. Endothelial cells of the capillaries of tongue (*а*, *б*, *в*) and brain (*г*, *д*) of a frog; osmium treatment according to Kolachev-Nassonov

г, *в*). One can find a series of transitional forms from the diffusely distributed osmiophilic substance to the typical Golgi apparatus.

In some cases the Golgi apparatus lies directly by the nucleus, on the cell side bordering the lumen of the capillary; in other, more frequent cases, the Golgi apparatus extends in the shape of a network alongside of the nucleus, oftenest of all only at one of its sides, but not infrequently surrounding it on every side. We see thus that the Golgi substance is encountered in the endothelial cells in three main phases: 1) as a substance diffusely distributed all over the cell plasm,

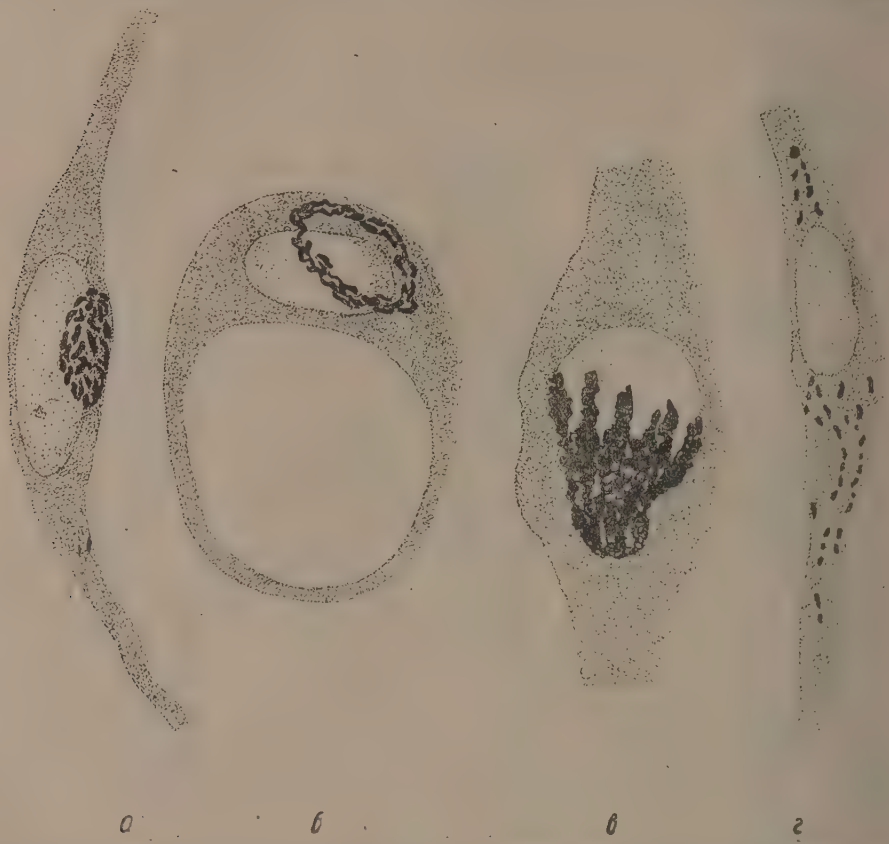

Fig. 2. Endothelial cells of the capillaries of a Malpighian tuft of a frog, silvered according to Aoyama (*а*, *б*, *в*); endothelial cell of a capillary of the tongue, stained according to Kull-Sekki (*г*); *а*, *в*, *г*—longitudinal sections; *б*—transversal section

2) as a separate, chiefly perinuclear osmiophilic zone, and, finally, 3) as a typical retiform Golgi apparatus (Figs. 1, 2).

It can be assumed that the distribution of the Golgi substance (*i. e.* of a definite specific lipoproteinic complex) within the endothelial cell in one case all over the plasm of the latter, in another only around the nucleus, in another again only along the interior or only along the exterior wall of the capillary's cells, must be of essential importance for the characterization of the continuously changing cytophysiological properties of the different parts of the capillary network.

Our observations show that the variation of Golgi substance within such wide limits is characteristic of the endothelial cells of the capillaries of some organs only (*e. g.* brain, heart, tongue), while in others (lung, kidney) it is more limited, and the Golgi substance is encountered usually in the forms typical of the Golgi apparatus.

It should be added that our observations permit to affirm that vitamin C in the endothelial cells is closely bound with the Golgi substance. It can be considered that the Golgi apparatus serves as a depot for vitamin C.

Mitochondria—the carriers of numerous ferments and vitamins—are, as a rule, comparatively scarce in endothelial cells, small in size and stain not so readily as in preparations of most other tissues. This may serve in a certain measure as an indication of a certain distinctive character of the endothelial mitochondria.

Of the reserve substances of the cell we studied, with the aid of Bauer's technique, glycogen: the endothelial cells of the capillaries of the frog's brain and tongue and of the brain and tongue of the white mouse, in contradistinction to the cells of many other tissues, as a rule, contain no glycogen.

There is ground to believe that the mineral substances of the endothelium of capillaries participate in the barrier and metabolic functions. Proceeding from this it seems of interest to study the character of the localization of mineral substances in the cells of the blood capillaries of organs with a different essential function. In the literature there are no data whatever regarding this question.

The necessary analysis was performed by my collaborator N. Skadovskaya by means of microincinerating sections of frog liver, kidney, brain and lungs, after fixation with a mixture of absolute alcohol and formol. The ignited preparations—spodograms—reproduce the structure of the tissue, allowing at the same time to study the ash residue of the endothelium.

The study of the spodograms of organs of a great number of frogs allowed us to establish that a high content of mineral substances in the nuclei and a very insignificant one in the plasm is characteristic of the endothelium of the capillaries of the organs tested. The amount of mineral substances in the plasm of the endothelium of different organs is different. It is highest of all in the endothelium of the lung capillaries and somewhat less in those of the kidney. The plasm of the endothelium of the capillaries of the brain and liver contains only traces of ash, however, on rare occasions here also one may see under the microscope ash in a capillary wall. Unequal distribution of mineral substances along the wall of the capillary is a characteristic feature. The endothelium of the lung and kidney capillaries contains much calcium and some silicium, mainly in the nuclei. Iron is present only in traces. Nothing can be said of the other mineral elements, since there are no satistactory methods for their determination in spodograms.

The above said and the results obtained by us earlier permit in their totality to give a definite histophysiological characteristics to the endothelium of capillaries.

Our observations have revealed in endothelial cells: 1) certain distinctive features in the different parts of the capillary network in respect of the colloidochemical properties of the plasm and nucleus, revealed by means of Pischinger's technique; 2) the scarcity of mineral substances in the plasm; 3) dynamic changes in the Golgi substance; 4) certain peculiarities of the mitochondrial apparatus; 5) high vitamin C content; 6) absence of glycogen.

Finally, we must note that the endothelium of different organs is not of the same type and shows numerous cytophysiological differences.

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ECOLOGY

ACCLIMATIZATION IN *DAPHNIAE*

By V. M. KOROVINA

(Communicated by I. I. Schmalhausen, Member of the Academy, 8.VIII.1944)

The purpose of the present work was to investigate acclimatization of hydrobionts under experimental conditions. *Daphnia magna* individuals were taken as a material for this investigation, since they are eurytopic and plastic organisms, readily cultivated and multiplied under laboratory conditions. The experiments involved acclimatization to high temperatures. For the preliminary series of experiments the individuals were taken from a population. But since the temperature reaction of *Daphnia* was found to be variable, the progeny of a single female was used for the subsequent experimental and control series. The purpose of this procedure was to minimize the genotypic variability and to eliminate variability due to age differences. The latter was of particular importance, since preliminary observations on young individuals showed them to be much more resistant as compared to mature ones.

Daphnia magna individuals which had to be acclimatized to high temperature were kept from 1 to 7 days at a sublethal temperature ranging from 29 to 32.5°C, after which they were transferred to room (control) temperature. Control individuals taken from the same brood were kept at room temperature (+15° C). The treated and control series were then compared with respect to their survival after additional transitory treatment with sublethal temperatures (37.0÷39.5° C). A total of 28 experiments were carried out, the experimental conditions being different with respect to temperature, period of acclimatization, and the subsequent transitory temperature treatment.

Individuals that had been subjected to the action of sublethal temperature during one day were found to be more resistant to high temperature as compared to the control ones. For example, the control individuals that had been subjected to temperature influence at 38.5° C during 14 minutes died within 24 hours; individuals that had previously been acclimatized were found to survive a subsequent temperature treatment applied during 50 minutes. This phenomenon of increased resistance was observed more than once. It developed in *Daphniae* during two days and did not increase afterwards. An increase of this resistance was observed in the case where the individuals to be tested were taken not directly from the sublethal temperature, but after they had been left for 24 hours in normal temperature (+15° C). The resistance is reduced if this «respite» is protracted.

The experiments involving acclimatization to low temperature were performed at 6° C. After a treatment with this temperature, the experimental individuals were transferred to normal temperature. Then their response to an additional transitory temperature treatment (at —3° C) was tested by the method of comparison of viability in both series. It was found that individuals allowed to stay during 48 hours at 6° C showed an increased resistance to lower temperatures.

This effect was found to be strengthened if the individuals tested were allowed «to rest» after acclimatization treatment during 24 hours. For example, individuals which had been subjected to 6° C during two days and allowed to «rest» at 15° C during 1 day, feel well when kept afterwards at—3° C during 45 minutes. Unlike this, the controls transferred from 15 to—3° C for 10 minutes died within 24 hours. The resistance is developed during two days. It was not strengthened by the prolongation of acclimatization period, and decreased as the «resting period» was prolonged.

The other series of experiments showed that the individuals that had been acclimatized to low temperature were less resistant to high temperature as compared to the control ones. On the other hand, individuals acclimatized to high temperature were found to be more resistant not only to higher, but to lower temperatures, as well. 21 experiments performed by us went to confirm this observation. As it seemed possible to suggest that the resistance acquired during the experiments here described was no specific one, an additional series of experiments was carried out. The purpose of the latter was to compare the resistance of individuals acclimatized to higher and lower temperatures to chemical factors. These were as follows: ammonia solution (0.2 and 0.15 per cent) and lactic acid solution (0.022—0.026 per cent). However, no difference was found in the reaction to the chemicals tested in *Daphniae* acclimatized to the different temperatures and in control individuals.

It is evident that the difference in the reaction of *Daphnia* individuals to the high and low temperatures is closely connected with their resistance developed in the process of natural selection. Natural selection in *Daphniae* has led to the survival of individuals adapted to higher temperatures prevailing in the upper layers of water during the summer period. No such selection with respect to low temperature could take place in nature, since during the autumnal period the *Daphniae* perish as the temperature decreases, and it is selection for the resistance of eggs rather than adult individuals which takes place. The resistance to high temperatures which was developed in our experiments under the influence of sublethal conditions, combined with the resistance due to natural selection, brought about a high plasticity of the organisms with respect to the temperature factors in general. If the acclimatization to lower temperatures takes place under laboratory conditions, the resistance fixed by the natural selection is artificially decreased. This is the cause why individuals that had been acclimatized to low temperatures were found to be more sensitive to high temperature.

The increase of resistance of acclimatized individuals under the influence of «rest» can be explained on the assumption that sublethal temperature causes a strong intensification of metabolism and reversible changes in the protoplasm. A 24-hour «rest» under normal conditions is sufficient for recovering from plasmatic disturbances induced and for regulation of metabolism at a normal level. Further investigations will answer the question as to the possibility of fixing the resistance acquired within the treated and the subsequent generations, be it even in the form of «Dauermodifikation».

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PLANT PHYSIOLOGY

DAYLENGTH AS A FACTOR DECISIVE FOR THE POSSIBILITY OF THE EXISTENCE OF A SPECIES

By N. N. KONSTANTINOV

(Communicated by B. A. Keller, Member of the Academy, 22. X. 1944)

The phenomenon of photoperiodism which was discovered by Garner and Allard in 1920 is still the subject of extensive research on the part of plant physiologists. In the course of such studies there arose the problem on the biological rôle of the reaction of plants to the length of day illumination. A number of scientists ([3,5,6,9,11]) have demonstrated a definite regular relation between the photoperiodic type of the plant and its geographical origin. It has been proved that the so-called plants of short day originate, as a rule, from lower latitudes, while the plants of long day belong to northern regions where the length of the diurnal illumination during the growing period is considerably greater than in the southern ones. Most thoroughgoing studies along this line were carried out by Razumov and Doroshenko ([1,2]). Garner ([10]), on the basis of his own experiments, has introduced the conception of the «critical length of day», *i. e.* a length of day the increase in which makes a plant of the short day lose the reproductive ability and, conversely, plants of the long day, gain this ability. Experiments by Moshkov ([7]) have subsequently demonstrated a remarkable sensitivity of plants grown under photoperiodic conditions approaching the «critical» ones, when 10—15 minute-long intervals were decisive for the ability of the plant to pass to reproductive stage. Katunsky ([4]) regards the photoperiodic reaction as an accomodation which regulates the rate of passing and the very possibility to enter the stages and developmental phases of a vegetable organism.

Our studies of the cotton-plant with regard to it photoperiodic reaction have furnished support to the view that the reaction of the plant to the duration of illumination has a biological, or adaptive importance. It has been shown ([5]) that in cotton forms of equatorial origin the critical (threshold) duration of illumination was less than in forms which originated from higher latitudes. Similarly, the optimum length of day is less in the former than in the latter.

The study of the biological properties of *Gossypium Thurberi* Tod. has shown that the length of day may, under a given set of surrounding conditions, determine the very existence of the species.

Gossypium Thurberi Tod. is a wild species occurring in North Mexico and South Arisona, *i. e.* at latitudes from 31 to 34°. The maximum length of the summer-day attains there 14 hours. Special experiments conducted by us have shown that the critical length of day in this species approximates 14 hours. This conclusion has been verified by the study of *Gossypium Thurberi* Tod. under natural conditions prevailing in Central Asia.

At Tashkent *Gossypium Thurberi* Tod. starts blooming and fruiting not before the 20—25th of August when the natural length of day approaches 14 hours. In plants of different ages and of different dates of planting grown under different conditions normal development of the flower-buds into flowers and bolls takes place after this date. The plant is unable to reproduce normally prior to this date, since the length of day attains at Tashkent in June and July 15—15.5 hours.

Tests made at Takhta-bazar (Turkmenian SSR) have shown that *Gossypium Thurberi* Tod. begins reproducing there about 15 days earlier than at Tashkent. This depends on the fact that Takhta-bazar is 4° farther South than Tashkent so that the day attains there its critical length by about 15 days earlier.

The study of *Gossypium Thurberi* Tod. leads to a conclusion that the length of day is of paramount importance for the reproductive ability of the plant. It has been proved that while this species forms 2—3 bolls per plant with a 7—10-hour-long day and 10—15 bolls with a 10—12.5-hour-long day, it is able to produce as many as 400 fruits per plant with a 13.5—14-hour-long day. The length of day approximating 13.5—14 hours appeared to be the optimal both for a rapid transition to the reproductive stage and to a relatively fast growth, resulting in a greater number of fruits formed towards the autumn.

Gossypium Thurberi Tod. differs from the typical representatives of the group in a number of morphological and biological peculiarities. One of the properties of this species which is of interest to breeders is its extreme cold resistance. According to our observations, *Gossypium Thurberi* Tod. can survive temperature drops down to 5—6°. This peculiarity of the species in question is evidently a result of its preceding phylogenetic history which passed under the conditions of higher latitudes.

Another interesting feature of the species named consists in its extremely hard seed coat. Lignin which impregnates the seed coat makes the latter so hard and unpermeable that ordinary methods for germinating seeds of *Gossypium Thurberi* Tod. fail (3).

Such a hard seed coat is peculiar of the majority of wild *Gossypium* species. Hard seed coat in wild *Gossypium* species is a mighty biological agent of self-defense against external influence; it is a means of regulating the water content of the seed, it guards the seeds against mechanical damage, *etc.* This property disappears in cultivated and semi-cultivated cotton of later origin, while the rôle of a regulator of humidity is to some extent played by the pappus.

An idea of the important protective rôle of the hard seed coat in *Gossypium Thurberi* Tod. may be gained from the following observations. In 1942 we conducted experiments at one of the plots of the Central Breeding Station on the reaction of *Gossypium Thurberi* Tod. to reduced daylength. The plants were grown with shortened or normal daylength. Plants grown under shortened day produced fruits abundantly, and a considerable quantity of seeds dropped to the ground.

Next spring the lot which had served for the experiment was ploughed, and cotton seed was planted on it. On the spot where *Gossypium Thurberi* Tod. was grown the previous year, some seedlings of *Gossypium Thurberi* Tod. resulting from the autumn spontaneous insemination appeared nearly simultaneously with the seedling of the cotton planted in spring.

Owing to their hard coat the seeds of this species, being distributed over the surface of the ground, could survive the unfavourable conditions of the winter months with their changing temperature, moisture, *etc.* During the winter a slow process of decay and of breakdown of the seed coat took place, which made it possible for the seeds to start growing in spring.

Artificial selection in *Gossypium* evidently proceeded in the direction of isolating forms possessing a less hard seed coat than that of the wild species described above; they were less adapted to competition with the wild forms under natural conditions, but more suitable to man.

What is then the way to explain the fact that *Gossypium Thurberi* Tod. has a rather limited area in spite of its valuable biological property? Migration towards the South was probably prevented, first, by the absence of accomodation for seed transport, particularly of pubescence, owing to which the seeds of cotton might be transported by water and birds. Secondly, the conquering of new areas was handicapped by the weak growth of the plants at the initial stage of development, which is typical of *Gossypium Thurberi* Tod. The plants of this species were weeded-out by the opulent vegetation of the tropical and subtropical regions.

Migration towards the North, aside from the above factors, was prevented by the length of the day in the northern regions, which was not suitable to the development of the species in question.

Indeed, the experiment described above has shown that the seeds of *Gossypium Thurberi* Tod. can survive winter under the surroundings of Tashkent, and that this species can become a weed on our fields. However, this is rendered impossible by the non-suitable length of the summer-day at our latitudes.

As mentioned above, *Gossypium Thurberi* Tod. begins to reproduce, under normal conditions of Tashkent, not before the 20—25th of August, so that the seeds have no time to mature before the first frosts. Only under the conditions of reduced daylength do we obtain the possibility of producing mature seeds of this species.

The existence of *Gossypium Thurberi* Tod. under the conditions of Tashkent is consequently made difficult not by the relatively severe winter conditions, but by the unsuitable length of the natural summer-day which prevents the species in question developing mature seeds prior to the first frosts.

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PLANT PHYSIOLOGY

VARIATION IN SUCKING POWER OF LEAVES IN EGYPTIAN COTTON CAUSED BY DIFFERENT IRRIGATION REGIMES

By A. T. KRAPIVINA

(Communicated by A. N. Bach, Member of the Academy, 20.IX.1944)

In our studies on the water regime and development of Egyptian cotton (variety 23) under field conditions with various irrigation regimes we were able to make some observations on the variation in the value of the sucking power of the leaves throughout the growing period. The work was done in the Vakhsh valley at the State Farm «Kirov» on heavy irrigated soils which are typical of this valley ([3]).

The experiments on the irrigation were carried on by A. V. Nikolaev, while our work was confined to physiological observations on the experimental plants under various conditions.

The following set of experiments was arranged: 1) Moisture of the soil constantly kept at 80 per cent of the capacity; 2) water content of the soil varying between 100 and 60 per cent; 3) same, from 100 to 50 per cent. The depth of penetration of the root system was determined for the separate developmental phases of the plant. During the growing period in all the experimental sets there were three tillages, four cultivatings and five times furrows were made. Fertilizers were introduced in quantities so as to make 60 kg P_2O_5 and 90 kg N per hectare.

Observations on the condition of the cotton-plant have shown that the first set (80 per cent of the moisture capacity) was the most favourable one. The most unfavourable set proved to be the third one (100—50 per cent). Plants of the first lot have not experienced any considerable shortage of water, except during a very short period in July. At this period there was only a slight shortage during the daytime, so that the plants showed some withering about noon. In the remaining two sets there was observed during a certain interval a residual deficiency of water, as shown by a considerable withering of the plants early in the morning. In other words, no restitution of turgor took place during the night. In the set «100—60 per cent» this morning withering lasted 2—4 days only, while in the set «100—50 per cent» it lasted 8—10 days. The yield of raw cotton appeared to be correlated with water supply. The yield produced by the plants of the first set was 40.8 centners per hectare, while those of the second and third sets were 12.5 and 10.7 centners, respectively. Thus, a relatively small residual deficiency and a corresponding increase in the osmotic pressure and sucking power have caused an exceedingly strong reduction in yield. It is of interest to compare the data on the yield with the osmotic pressure and sucking power, the more so as the possibility to diagnosticate the irrigation through the observation of the physiological characters was discussed in literature. Thus, Shardakov([4]) recommends to irrigate cotton according to the sucking ability which is not likely, as he thinks, to exceed 13 atmospheres. Irrigation according to the sucking abi-

lity was studied by Golodkowsky, Nezhina and Mednis at the Ak-Kavak and Ferghana Experiment Stations of the All-Union Institute for Cotton Industry.

For the study of the sucking ability of the leaves Shardakov's method was applied, which is an elaboration of the method by Arzikhovsky (1). Determina-

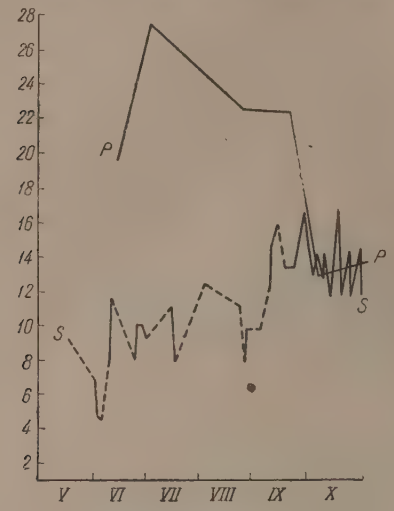

Fig. 1. Set 1 (moisture 80 per cent of limit capacity)

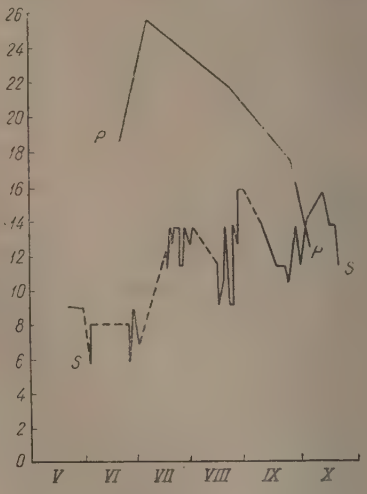

Fig. 2. Set 2 (100—60 per cent moisture)

tions of the sucking power were made by us three times a day from June to October, at the periods between irrigations. Along with the study of the variation in the sucking power of the leaves we studied also the variation in the osmotic pressure of the leaf-sap at different developmental stages, throughout the growing period, by the method of Bardger. To avoid drying of the capillaries containing the solution (which occurred otherwise very rapidly under the conditions of the Vakhsh valley, thus preventing the measurements) we had to place them into moist chambers.

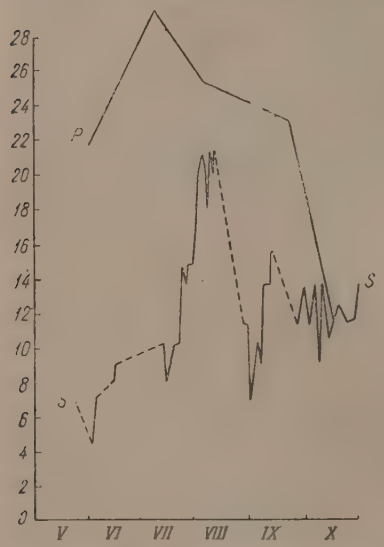

Fig. 3. Set 3 (100—50 per cent moisture)

The variation in the sucking power during the day was not very strong in our experiments (from 2 to 3 atmospheres). The slightest variation was observed in the first experimental lot (80 per cent), and a somewhat larger one in the two others. The sucking power attained its maximum at 14 o'clock, but on some days the maximum was observed at later periods of the day. A considerable increase in the sucking power occurs during the growing period. In spite of a frequent irrigation which results in certain reduction of the sucking power, the absolute value of the latter increases steadily. This is probably connected with the general increase in osmotic pressure with the age of the plant (2). It can be observed from the adjoining diagrams that the osmotic pressure grows in all the experiments till the beginning of August; after this date there begins a decrease which is evidently connected with fructification. The value of the sucking power continues growing until September and approximates that of the osmotic pressure.

In Figs. 1—3 are presented diagrams of the osmotic pressure, P, and of the sucking power, S. Solid lines of the curves S refer to the period between irrigations; the dotted ones, to the period of irrigation.

The drop in osmotic pressure at the period of fructification is evidently connected with the strong expenditure of reserve materials on the growth processes. The considerable value of the sucking power possibly depends on the high intensity of the meteorological agents at this time; the same phenomenon at the end of vegetation may depend on the arrest of irrigation.

The sucking power observed in the remaining two sets was considerably greater than in the first set. Even the most favourable set undoubtedly showed at a definite period a rather high sucking power, which did obviously tell upon the yield, although its absolute value is rather high. This set produced in the preceding years still higher yields of raw cotton, evidently owing to a more even distribution of water and to the absence of jumps in the value of the sucking power.

From the fact that the value of the sucking power varies greatly at different developmental stages of the cotton-plant it follows that, when irrigating according to the sucking power, a differential approach is necessary, and the maximum admissible values of the sucking power should be set forth under consideration of the developmental stage of the plant. Assuming that the plants of the first lot (80 per cent) were placed into favourable conditions of the moisture regime, the following gradations of the sucking power may be accepted as guiding indices for irrigation at Vakhsh valley. Prior to budding the value of the sucking power should not exceed 6—7 atmospheres; during these stages, 6—8 atm.; during blooming, 8—10 atm.; at the time of fructification, 9—11 atm.; and at the period of the opening of bolls, 12—13 atm. Referred to monthly periods, the values will be as follows: May, 6—7 atmospheres; June, 7—8 atm.; July—August, 8—11 atm.; September, 12—13 atm.

It should be noted that we have not tried directly to adapt irrigation to the sucking power, but we think that in corresponding trials one should take into consideration the developmental stage of the plant and determine the limit value of the sucking power for each developmental period separately. It is very probable that insufficient attention paid to this point may in some instances lead to disappointments as to the practicability of the irrigation after sucking power, in spite of the fact that this method is quite correct in principle, since the need in irrigation is evaluated from the condition of the plant itself.

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PHYTOPATHOLOGY

DETERMINATION OF THE ISOELECTRIC POINT OF VIRUS PROTEINS BY THE STAINING TECHNIQUE

By L. M. TARASSEVICH

(Communicated by A. A. Richter, Member of the Academy, 26.X.1944)

It was found by many authors ([7], [9], *etc.*) that the staining of live and dead tissues depends on the pH of the staining solution. The ground of this dependence is the difference between the electric charge of the staining solution and that of the substance which adsorbs the stain. The stain is fixed only by structures possessing an opposite electric charge. Acid stains with a coloured anion stain readily tissue proteins at low pH values of the staining solution; basic stains, on the contrary, at high pH values. At their isoelectric point the cellular proteins are not stained either by acid or by basic stains, because they are electroneutral.

Drawert, staining plastids in the leaves of *Helodea canadensis*, found that, being stained with acid fuchsin at pH=1.3—3.1, the plastids acquire an intense red coloration; with the increase of the pH of the staining solution the intensity of coloration decreases, and at pH=5 the plastids cease to stain altogether.

Toluidin-blue, contrariwise, does not stain the plastids at pH = 1.3—3.1; they begin to stain blue from pH = 4.5 upwards, the intensity of coloration increasing with the rise of the pH value.

Pischinger, staining animal tissues at varying pH values, with an acid stain, cyanol, and a basic one, toluidin-blue, demonstrated the same dependence of staining on the pH value and utilized it for determining the isoelectric point of animal tissues.

V. L. Rischkov proposed to us to try to utilize the dependence of staining on the pH for determining the isoelectric point of virus proteins.

The elaboration of a technique based on this dependence would enable us to determine the isoelectric point of those virus proteins, accumulating in plant tissue in crystalline form, purified preparations of which have not as yet been obtained and which present extreme difficulties in applying other available methods for the determination of the isoelectric point. To such viruses belong the *Nicotiana* virus 7, *Pisum* virus 2, *Phaseolus* virus 2, *etc.*

Moreover, this simple method might prove useful in the determination of the isoelectric points of sparingly soluble virus proteins, as *e. g.* the virus of silkworm jaundice (Bergold and Schramm), whose isoelectric point is very difficult to determine with the help of the precipitation technique. The new technique would enable us to distinguish morphologically similar virus crystals, such as *e. g. Nicotiana* virus 1 and *Cucumis* virus 2.

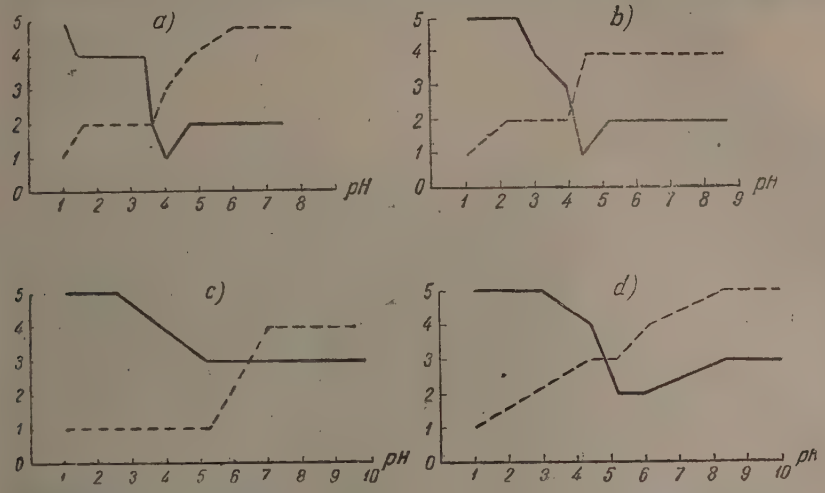
It should also be reminded that in the reports referred to above ([9], [10]) the applicability of the staining technique to the determination of the isoelectric points of cellular proteins was not proved beyond doubt, since these proteins are inaccessible to any other technique of determination of the isoelectric point.

Gelatine which had served to Drawert as a model differs to much by its properties from the structural proteins of the protoplasm. The crystals of virus proteins, both by their chemical composition and by their structure, are by far more perfect models of protoplasmatic elements ([3]).

Consequently, by staining virus crystals at different pH values of the staining solution, we should be able to establish more precisely the degree to which this technique is suitable for histological application. Up to the present the isoelectric point of virus proteins was determined chiefly by means of the electrophoretic and precipitation techniques.

The staining of virus crystals has been studied earlier by Rischkov ([3]), Klemparskaya ([3]) and Kausche ([1]). It has been shown by these authors that virus crystals are stained readily both by acid and by basic stains, particularly after treatment with various fixing solutions (alcohol, picric acid, formol, *etc.*).

For our work we took, as acid and basic stains, 10 per cent solutions of acid and basic fuchsin. Fixation was done with 96° alcohol. The stains were mixed



Dependence of coloration of virus proteins on pH of staining solution. Coloration by acid fuchsin is shown by continuous line; that by basic fuchsin, by the dotted one. *a*, virus of tobacco mosaic; *b*, virus of cucumber mosaic; *c*, virus of «zakuklivanie»; *d*, polyhedra

with the various buffer solutions in a ratio of 1 : 1. The buffer solutions used were the phosphate-glycocol mixture and the mixture of McIlven. The pH of the buffer solutions were checked electrolytically.

The objects used for the tests were:

1) A preparation of the paracrystals of the virus of tobacco mosaic *Nicotiana* virus 1, purified according to the method of Rischkov and Gromyko and suspended in a solution of $(NH_4)_2SO_4$.

2) A preparation of the virus of cucumber mosaic *Cucumis* virus 2, purified by the same technique.

3) Crystals of the «zakuklivanie» virus obtained from dry material according to the technique recommended by Sukhov ([4]).

4) Polyhedral crystals of silk-worm jaundice washed several times with water.

The difficulties encountered in staining polyhedra are well known. For our tests we used polyhedra staining readily in their interior part, and the isoelectric point of their protein was determined on the ground of the coloration of this interior part.

A drop of the preparation was placed on a slide, dried in the air, fixed with 96° alcohol and stained with the buffer staining solution for 5 min. After this the stained film was washed with the corresponding buffer solution and was ready for microscopic examination.

The results obtained have been reproduced in graphic form (cf. figure). In the graph the intensity of staining is reproduced on a 5-mark scale. It is visible in the figure that in every case the virus crystals stain readily with acid fuchsin at low pH values, and with difficulty, at high ones. For basic fuchsin the relations are reversed.

Evidently, the pH value which corresponds to the least intensity of coloration with acid fuchsin at low pH and with basic fuchsin at high ones, corresponds at the same time to the isoelectric point of the tested virus protein. Taking the average of the pH values corresponding to the least intensity of their staining by acid and by basic fuchsin, we obtain the following values for the isoelectric points of the virus proteins tested (cf. table).

Isoelectric Points of Virus Proteins Determined by Means of Staining Technique

Virus	Isoelectric point		
	Acid fuchsin	Basic fuchsin	Average
Tobacco mosaic	4	3.6	3.8
Cucumber mosaic	4.41	4	4.2
«Zakuklivanie»	5.6	5.2	5.4
Polyhedra	5.2	5.2	5.2

Let us compare our results with the literary data available.

The isoelectric point of *Nicotiana* virus 1, as determined by precipitating the protein in the presence of salts, lies at pH = 3.3. This value may vary according to the conditions of the test within the range of several tenths ([5]). The isoelectric point of the virus *Cucumis* 2 lies somewhat higher; in the presence of salts this virus is precipitated at pH = 4.8 ([5]). The virus of «zakuklivanie» is precipitated, according to Sukhov ([4]), at a pH value of about 5.0 ([4]). The isoelectric point of the polyhedra of *Bombyx mori* was determined by Bergold and Schramm ([6]) with the aid of electrophoresis as lying at pH = 5.3—5.6.

Considering the close dependence of the isoelectric point on various factors (electrolyte concentration, method used for the purification of the virus, *etc.*), one must acknowledge that our results show a sufficient coincidence with the data obtained earlier by means of other methods.

This is of particular interest because the material tested was subjected to a preliminary fixation with alcohol, and, consequently, such fixation does not affect to any considerable extent the isoelectric point of virus nuclear proteids. This circumstance speaks for the possibility of applying a similar method to histological work.

The proposed technique for determining the isoelectric points of virus proteins is distinguished by its simplicity, the simplicity of the necessary equipment and by its speed.

The chief disadvantage of the proposed technique is its relatively low precision, connected with individual differences in the evaluation of the intensity of coloration, inevitable in every research involving staining.

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EXPERIMENTAL MORPHOLOGY

EXPLANTATION OF EYE RUDIMENTS

By J. A. VINNIKOV

(Communicated by I. I. Schmalhausen, Member of the Academy, 8. VIII. 1944)

The following embryonic cell material of the eye rudiments was subjected to experimental study by the method of tissue culture in a liquid and solid explantation media (1): from amphibian embryos (axolotl and *Rana temporaria*) at the stage of gattrula, neurula, and caudal bud; chick embryos after 24-hour incubation; eye evaginations of the medullary plate in salmon embryo just marked off at the end of gastrulation and later.

The presumptive eye rudiments in amphibian embryos situated on the chordo-mesodermal substratum are represented by the multilayered sheet of prism-shaped cells. They contain the characteristic nuclei and are filled with yolk and small granules of an embryonic (egg) pigment. At these stages of development these rudiments are the only constituents of the whole medullary plate, differing from the latter by a more intense pigmentation of their cell elements. In fish and bird the eye rudiments are more or less similar to each other. They were excised either jointly or separately. In the first case the explants also contained the embryonic tissue of the prospective chiasmata; in the second case. precautions were taken to remove the adjacent tissues as carefully as possible.

Amphibian eye rudiment was excised and placed into the liquid medium; within a few hours after explantation it becomes round in the shape, turning into a dense, non-transparent at first and spherical body, containing a small cavity that can be seen on the sections.

Further observations showed a number of interesting regulative transformations. Some part of the elements «shed» and died throwing out their yolk contents. The yolk granules could be thrown out by the living cells also. Owing to the selective reaction to the medium, part of the elements of the piece explanted was found to remain on the surface, while another part of them sinks in the explant. The sinking of the material usually takes place in a definite point of the explant, by way of formation of a peculiar «blastopore». The superficial cells, covering the rudiment, are intensely proliferated and become gradually free of yolk and pigment, permitting of *in vivo* observations of the inner parts of the explant which gradually become more and more transparent. The coat elements consist of a single layer of cells cubic or flattened in shape, having sometimes motile cilia. In relation to their histological features the superficial cells differ strongly from those of the epidermis which develops from the epidermal rudiment, and look like the medullary ependymal substratum rather than the epidermis. This similarity is also strengthened by the presence of the parts of the developing olfactory placode. The ependyme coat of the explant is lying on the substratum made up of star-shaped or spindle-shaped cells connected with one another.

They are probably meso-ectodermal in origin ([2]) and very similar to those of the lophioderm, which separated from the remaining bulk of the inner tissue of the explant. Thus, the latter are separated from the liquid explantation milieu by the ependyme coat, and develop in the inner milieu of the explant which is represented by the mesenchyme.

After having sunk inside the explant, the elements transformed into a medullary vesicle from which 1 or 2 optic vesicles were cut off. In the latter case their arrangement was symmetrical. The lumen of the medullary and optic vesicles is as it were a particle of the external milieu which sank inside the explant. The unpaired eye was sometimes found to be cyclopean or synophthalmic. The right or left rudiment when cultivated separately gives rise to one, or more rarely two eyes. In the latter case they were somewhat smaller in size.

The optic vesicles develop into the optic cups. Owing to an intense proliferation of the cells, the edges of the latter give rise to lenses which underwent a characteristic differentiation. The cups are fairly well seen through the coat layer and become very contrasting after the development of tapetum pigmentation. They are connected with the small medullary vesicle by means of the optic stalk. The intermediate medullary vesicle resembling by the outline of its lumen the mid-brain of *Amphibia* shows the typical medullary differentiation. The superficial parts of the olfactory placode mentioned above are located near or opposite this vesicle. Towards the 15—20th day of cultivation, more or less regular processes are observed in the inner layer of the eye-cup. They are completed in the formation of all the retina layers, inclusive of rods and cones. The latter were found to contain the visual purple which discoloured under the influence of the light.

The location of the substratum of the rudiment on the phase separating, in the case here considered, the inner milieu of the medullary tube (*i. e.* the cavity of the primitive eye vesicle) from the inner milieu of the explant, plays an important rôle in the polarization of its histogenetic processes, and causes the possibility of the realization of the tissue interrelations arisen during phylogenesis. The differentiating elements migrate in an orderly sequence in the direction to the inner milieu, this process involving, first, the ganglion cells, then the elements of the inner nuclear layer, and, finally, the external cambial layer.

The development of the parts of the mid-brain from the eye rudiment testifies to a profound morphogenetic connexion between the eye-cup and the brain, which Filatow ([3]) was the first to point out. It should probably be accounted for by the phylogenetic and ortogenetic integrity of all the parts of the optic system, *i. e.* the genetic proximity between its links located in the retina and in the brain. Under experimental conditions all the steps of the development of the optic system are reproduced by way of regulation, thus demonstrating the morphogenetic integrity of the optic system.

The organotypic explants described above existed as long as the integrity of the coat did (2—3 months). Ultimately such explants died because of a total consumption of yolk and of the disturbance of the metabolic processes.

The eye vesicles explanted at the stage of the caudal bud also developed in the liquid explantation medium, with the difference that they were completely incapsulated in the epidermal sac. However, the organotypic and histological differentiation did not reach the level observed under similar conditions for the earlier stages. The phenomenon under comparison is probably connected with the peculiar sensitivity of the rudiment to the external conditions ([4]).

The amphibian eye rudiment explanted into a solid medium composed of plasm and extract mixture showed a quite different behaviour. It was possible that the fibrin clot prevented the formative movements of the individual cells and, therefore, the formation of the isolated inner milieu of the explant. On the other hand, the chemical composition of the explantation milieu was in this case nearer to the normal, physiological one. Owing to this, the regulative mechanism of the rudiment here described was suppressed and, consequently, instead of ad organotypic systemic metamorphosis, there was observed the formation of a broan

disorganized zone of extensive growths, from primarily indifferent elements filled with yolk. This zone spread upon a fibrin clot or mica. Then the following elements were observed to arise in the growing zone: peculiar pigmented regions looking like strands, or sheets consisting of polygonal two-nucleated elements characteristic for tapetum; chromatophors of different colour; non-pigmented epithelial membranes with finest fibres; isolated cells varying in form and size; elements similar to neuroblasts having typical nervous branched outgrowths, located in the rounded liquified regions of the growing zone and disappearing towards the 30—40th day of explantation.

In some cases where the period of cultivation was of medium duration, there were observed elements of rods and cones. Differentiation of the latter was so advanced as to show the presence of the lentoid and the phenomenon of Kolmer's secretion. Thus, the proliferating elements of the growing zone passed through specific cytohistological differentiation corresponding to the general potencies of the cells of the rudiments. At later stages of cultivation, because of outgrowing of its elements, the zone of growth completely reproduced all the structures of the glial type established by Chlopin ([5]) a sa new member of the natural tissue system proposed by this author.

The eye rudiment of the salmon underwent epithelization in the liquid explantation medium. Owing to this, the developing eye-cup was throughout covered by the epidermal lining from which the lens developed. The development of the pigment could be observed in the external eye-wall. Characteristic histogenesis of the retina layers took place in the elements of the internal wall that underwent extensive proliferation. On the contrary, in the solid explantation medium there were observed only extensive, flattened, mostly pigmented outgrowths. It is a matter for regret that the explantation of this insufficiently studied material could not be extended to more than 5—8—15 days.

The chick eye rudiment developed only in a medium consisting of the extract and plasm ([6],[7]). However, the fibrin was found to liquefy around the piece explanted, and in these cases the explant showed organotypic metamorphosis. The rudiment developed into a typical eye-cup with the «epidermal» lens and differentiating elements of the internal and external walls. At the same time the peripheral parts of the explants showed an extensive growth. The ingrowing was so fast as to involve after some time the elements of the cup-wall into the zone of growth, and in the latter they underwent further cytological differentiation (*i. e.* pigmentation). After 20—30 days of cultivation the zone of growth was found to possess features characteristic of the glial type, in which it was possible to note a number of cytological and histological peculiarities connected with their origin from the avian eye rudiment.

The results obtained permit of definite conclusions as to the peculiarities of the *in vitro* development of the elements of the eye rudiment. In his analysis of the organogenesis of the isolated primordia and of the eye rudiment, in particular, Holtfreter ([2]) came to the conclusion that their development does not depend upon the explantation medium. In his opinion, it depends upon the dynamic peculiarities of the rudiment, which consist in the alternation in time of the positive and negative affinity between the different elements of the primordia and the surrounding tissues. In other words, the development of the whole organism depends upon the development of its parts.

However, as shown by a thoroughgoing investigation, the behaviour of the embryonic eye rudiments in liquid medium *in vitro* is largely due to its interaction with the explantation milieu.

As mentioned above, owing to the reaction between the selective system of the separate rudiment elements, there arises an internal explant milieu of its own in which a part of the elements of the rudiment is immersed. Thus, the organogenesis seems to be brought about on the phase separating the internal medium of the explant from the explantation medium. Such a location of the substratum can be considered as an initial morphogenetic reaction ([1]). The formation of an inner tissue milieu isolated from the outer one by means of the coat,

led to the development of the form of the explant, and then, as shown above, to the development of the eye-cups and the retina, in particular, whose histogenesis demonstrates fairly well the significance of the location of the substratum on the phase separating the two physiologically unequivalent milieux (7).

The phenomenon here described, characterizing the integrity of the rudiment which was re-established in a regulatory way, contributes to the preservation in the isolated system of those relations which existed in a whole embryo and were then observed *in vitro* (8).

Contrariwise, in the cases where explants were placed under conditions similar to those of the inner milieu, and surrounded by solid fibrin clot, it was possible to suppress the regulatory mechanism of the morphogenetic process of the rudiment. In such cases only irregular growth was observed followed by cytological and histological differentiation. In other words, differentiation was not connected with morphogenesis. In the normal development the morphogenesis and cytohistogenesis of the eye-cup are probably not so much dependent upon each other, as they do overlap each other in time. On the other hand, the interrelation and regular cytohistological differentiation of the rudiment elements are naturally to be determined by the systemic relations within the organisms as a whole.

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ZOOLOGY

ON THE DISCOVERY OF *PALAEACARIFORMES (ACARINA)* IN THE USSR

By A. A. ZAKHVATKIN

[*Communicated by E. N. Pavlovsky, Member of the Academy, 20.VIII.1944*]

Among the recent discoveries in acarology the most remarkable was undoubtedly the discovery by Trägardh in 1932 of a new suborder of mites to which he gave the name of *Palaeacariformes* (3).

According to this author, *Palaeacariformes* «are in many respects the most primitive mites existing nowadays». They are a kind of «living fossils», being related, on the one hand, to the most archaic forms of recent *Oribatei* and *Prostigmata*, and, on the other hand, to devonian *Protacarus* from the ancient red sandstone of Scottland. Thus, the importance of Trägardh's discovery was not limited to a mere finding of a group of so high a taxonomic rank, but it was also of great interest because of the extraordinary primitivity of the representatives of the suborder discovered.

Trägardh has described only two representatives of this group. One of them, *Palaeacarus hystricinus* Träg., 1932, was found in Sweden, in forest floor. The second one, *Archeonothrus natalensis* Träg., 1906, from South Africa, was first described by him as an aberrant representative of the *Nothridae* family. Later on four more members of this peculiar group were described by other authors: *Palaeacarus araneola* Grandj., 1932 (1), from material collected in Tangiers, Algiers and Venezuela (it was also found afterwards in termite hills in Brazil); *Acaronychus tragardhi* Grandj., 1932, from Tangiers; *P. appalachicus* Jacot, 1938; and *A. longipilis* Jac., 1938, from the USA (2). Moreover, Grandjean referred to the same group the genus *Parhypochthonius* Berl., 1905, which had been classed among the *Hypochthoniidae* family and consisted of three species: *P. aphidinus* Berl., 1905 (South Europe), *P. urticinus* Berl., 1910 (California), and *P. acarinus* Berl., 1910 (South and Middle Europe). The latter was described as a separate genus—*Aphelacarus* Grandj., 1932. We thus see that until the present time 9 rare species of *Palaeacariformes* have been described from Europe, Africa, and North and South America. They form 4 genera distributed among 3 families: *Palaeacaridae*, *Acaronychidae*, and *Parhypochthoniidae* Grandj., 1932.

At the same time the original opinion advanced by Trägardh with regard to this group of mites was essentially modified by Grandjean who believed the *Palaeacariformes* to be merely one of the numerous groups of lower *Oribatei*, «although it may well be the most primitive among them» (1), but which cannot claim at a rank of a separate suborder. They are most closely related to *Hypochthoniidae* with which they are connected through the *Parhypochthoniidae*. Later on this opinion was also adopted by Jacot (2).

Among the acarological material from different districts of the USSR, collected during 1938—1941 by my co-workers and myself in the course of our work on the distribution of grain-mites under field conditions, a number of new re-

presentatives of *Palaeacariformes* were found. Two of these were found to be species closely related to *Palaeacarus appalachicus* from North America. Together with the latter they constitute a new genus of the *Palaeacaridae* family, clearly distinct from the nominal one. Another representative was found to be a new species of *Aphelacarus* genus. Lastly, the fourth was found to be a peculiar member of the same family and undoubtedly a representative of a new genus. A brief description of these four forms is given below.

Tragardhacarus, gen. nov.

This genus is most closely related to the authentic *Palaeacarus* Tr., 1932, which is considered as the typical *P. hystricinus* but differs from the latter in respect to a number of characters. These are as follows. Tectum of the head shield is poorly developed, sometimes hardly noticeable. The skin coverings of hysterosoma more sclerotized and forming a system of the shields, poorly developed but clearly seen (these shields may be identified with the metapeltidium, propygidial and pygidial shields of other *Actinochitinosi*). Pigment is developed to a certain degree. There are 12 pairs of notogastral bristles on the abdomen (instead of 11, as in *P*). Two of them are represented by hairs; six by smooth bristles of the type peculiar to *Palaeacaridae*; four are represented by trimmed tubulous bristles, two pairs of which are very large and apparently mobile. The whole pattern of the bristle arrangement is quite different.

In addition, the following characters are to be considered as being peculiar to the *Tragardhacarus* genus: bristle-like flexible poorly trimmed trichobothriae; 3 pairs of aggenital, 5 pairs of anal and 4 pairs of preanal bristles. The genital valves having a pair of hook-like and strongly sclerotized appendices resembling the cocoonholder of certain *Pedipalpi*, and 6+3 hairs. There are only 2 pairs of genital suckers (the anterior one is probably lost). The armature of pedipalps corresponds to the formula 0—2—1—3—13—15. The general formulae of the leg armature are as follows: 0—4—6—8—11—36 (I); 1—3—6—6—8—27 (II); 2—2—4—5—7—22 (III); 2—3—4—5—8—24 (IV). Their solenidial formulae are as follows: 3—4—4 (I); 1—1—2 (II); 1—1—0 (III); 1—2—0 (IV). The didactilous nails are present on all four pairs of the legs.

Type of the genus: *Tragardhacarus lapshovi* sp. n.

As it was mentioned above, three species belong to this genus. These are: *Palaeacarus appalachicus*, 1938, from the USA, and two species described below, which were found in the USSR. I name them in honour of the two undergraduates of the Moscow University, I. I. Lapshov and A. F. Kamensky, who had died as heroes at the front of the National War.

Tragardhacarus lapshovi, sp. nov. Described on the basis of 3 samples from the vicinity of Kharkov (Ljubotin, in the forest underlying, 16.VIII.1939, found by A. G. Tremb.

The length (from the anterior edge of the tectum up to the posterior end of the body) is equal to 365—407 μ. The total length including chelicers is equal to 444—475 μ. The whole body and leg bristles are much longer than in the two other species of this genus. These relations are well illustrated by the table showing the length of their notogastral bristles against the length of opisthosoma (measured from the posterior end of the metapeltidium to the end of abdomen). The tarsus of pedipals have four simple ultimate and one subultimal acanthoids. The legs are considerably slimmer than those in the other species.

Tragardhacarus kamenskii, sp. n. is described on account of one specimen found nearly Orichevsk, Kirov district (in the forest underlying, 30.IX.1938, by S. V. Sorokin).

The total body length is 447 μ, body length is 370 μ. The bristles are considerably shorter than in *Tr. lapshovi* and *Tr. appalachicus* (see table). Tarsus of pedipalps has one triple ultimal pseudacantoid which is probably formed by the fusion of both larval (ul_1) and one pair of protonymphal (ul_2) (following to Grand-

Comparative Dimensions of Notochaetes in Three Species of *Tragardhacarus* (in per cent to length of abdomen)

Denotation of separate pairs of notochaetes (after Jacot, 1938)	*lapshovi*	*kamenskii*	*appalachicus*	Denotation of separate pairs of notochaetes (after Jacot, 1938)	*lapshovi*	*kamenskii*	*appalachicus*
a_1	65	52	34	c_1	110	86	74
a_2	89	67	58	c_2	5	3	3
a_3	40	31	26	c_3	116	88	80
a_4	5	9	7	c_4	84	77	88
b_1	96	59	70	d_1	4	2	3
b_2	190	147	178	d_2	70	78	92
b_3	212	158	176	d_3	126	93	112
b_4	96	70	68	d_4	86	67	86

jean terminology); one simple pseudacantoid ($z\,ul_2$) and three acantoids (two of them are ul_2 and one is unpaired subultimal).

Beklemishevia galeodula nov. gen.. n. sp. The general habit of the body and its segmentation and proportions resemble those of *P. araneola* Grandj.. 1932. a species which is obviously not related to *Palaeacarus* genus and is to be separated out as an independent genus. Propeltidium with a triangular tectum sharpened in front and a strongly prominent «occipit». separated by a deep furrow from the inclined back of the segment of legs II: the latter is. in turn. sharply separated from the metapodosome. The anterior part of the metapodosome has delicate transverse wrinkles; the posterior part of it is supplied with a metapeltidium. Opistosomal shields (propygidium. pygidium and pleural ones) are seen fairly well. Trichobotria hair-like. slender. slightly trimmed at the base. Abdomen (opistosoma) with 12 pairs of notachaetes, *i. e.* with obviously incomplete system (meritrichous. after Grandjean). b_3 and b_3 are very thick. tubular. densely trimmed throughout the length. mobile. but much shorter than the similar bristles in *Tragardhacarus*: d_2 and d_3 spindle-like inflated at the base and densely trimmed; c_3 and d_1 and one more (apparently. an extra one. as compared to *Tragardhacarus*) pair of bristles are strongly reduced: c_1 is probably missing: the remaining notogastral bristles are normal. There are 5 pairs of anal and 4 pairs of adanal bristles. The genital valves in front armed with a pair of hooks. sharply bent like those in *Tragardhacarus*: 6+3 pairs of hairs present. There are three pairs of genital antennae; of these the anterior one (protonymphal) is much shorter than the rest. Aggenital hairs are represented by 3 pairs. The armature of the palps is as follows: 0—2—1—3—16: one of the ultimal acantoid is double. The general formulae of the leg armature are as follows: 0—4—6—8—11—37 (I); 1—3—6—6—8—26 (II): 2—2—4—5—7—24 (III): 2—2—4—5—8—24 (IV). The solenidial formulae are the same as in *Tragardhacarus*. Legs I are didactilous; the other with hook-like *pseudonychium* between the two nails. The total length is about 370 μ .the body length is 325 μ. The description is given on the basis of 1 ♂ ad. and 1 tritonympha from the surroundings of Kharkov (VII. 1939. A. G. Treml).

The special interest of *B. galeodula* consists in that this form shows in the most demonstrative form a peculiar «ragoid» type of body segmentation which was considered as being peculiar to phalanges only. *Palaeacariformes* were found to be characterized by the same feature which is expressed to a different degree in different species.

It is a pleasure for me to name this form remarkable in many other respects after Professor V. N. Beklemishev.

Aphelacarus rossicus. sp. nov. is described on the basis of 1 ♀ found in the entomological laboratory of the Moscow University. in a container with grain. It is easily distinguished from *A. acarinus Berl*.. 1910 (which is the single spe-

cies of this genus known before) by a larger size (total length 468 μ, body length 411 μ). One of the bristles of the last segment of pedipalp (π 1t) has the same plumy structure as the anterior pair of adoral pedipalps. The femur has 2 bristles (instead of 1). There are 4 pairs of peranal bristles (instead of 5). In addition, there are many other less important differences. The general formulae of the leg armature are as follows (not described in the *Aphelacarus* genus) 0—4—6—7—10—26 (I); 1—3—5—6—6—14 (II); 2—2—2—5—4—12 (III); 1—2—2—4—7—12 (IV).

A detailed investigation of these four species has yielded many valuable data as to the organization of the *Palaeacariformes*, and their taxonomic relations to other groups of mites. A full description will be given elsewhere. It should be pointed out in this place that the results of the investigations achieved went fully to confirm Trägardh's assumptions as to the high degree of originality of *Palaeacariformes*.

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